Frontispiece Vol. V.

R. Parr Sculp

What is Man? Psalm 8.

Spectacle de la Nature:

OR,

NATURE DISPLAY'D.

BEING

DISCOURSES

On ſuch PARTICULARS of

NATURAL HISTORY

As were thought moſt proper to

To EXCITE the CURIOSITY

AND

FORM the Minds of YOUTH.

Illuſtrated with COPPER PLATES.

VOL. V.

Tranſlated from the Original *French.*

The FOURTH EDITION, Revis'd and Correcled.

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MDCCLXIII.

Pluche, Noël Antoine

TABLE of MATTERS

Contained in VOL. V.

N. B. The Machines referred to Page 263, are placed at the End of this Volume, with the Explanation of them.

Expla-

Explanation of the FRONTISPIECE of VOL. V.

WHAT IS MAN? *Psalm* viii. *David*, a simple Shepherd, admires the Extent of the Rights granted to Man, and is employed, in the Silence of the Night, in singing the Author of his Demesn. A fine Moon-shine shews him the Marks thereof round him. The Bow and Arrow, which in the Day Time search a Prey for him in the Air, lay on the Grass. A great Willow supports and dries, on the Water Side, Nets which draw out of it Part of his Food. The Oxen, unteamed from the Plough, chew the Cud, or lie still, waiting for the Return of the Sun, and their departing Order. His Dogs stand Centry. His Sheep in the Fold heat in part the Piece of Ground he wants to till; and the *Ursa Major*, by its Position, indicates to him the Hour when he must remove them from one Fold into another. The whole Earth countenances his Will; and Heaven itself rolls for his Service.

A PLAN OF THE LATTER PART OF *Spectacle de la Nature, &c.*

WHEN a great Monarch entertains his Court with ſome magnificent Spectacle, or his People with a public Rejoicing, 'tis a Pleaſure ſometimes to take a View of the Spectators themſelves, who are not the ſmalleſt Ornament of the Pomp. Our Attention having been ſufficiently employed on the aweful Scene of Nature, and the great Deſigns of him to whom we are indebted for ſo noble a Proſpect; let us now, Sir, fix our Eyes on Man, whom we ſee ſo honourably invited to it, and who is the only Spectator capable of diſcerning the Sumptuouſneſs of the Decorations, and the Beauty of the whole Diſpoſal.

But, let us not extenuate the Favour we have received, by looking upon it only as a tranſitory Amuſement: Not to acknowledge here our real Prerogatives, would be either falſe Modeſty, or downright Ingratitude. Nature is not a glorious Spectacle only, or the Joy of a Day: It is a beautiful Domain, with which Man is inveſted for a Series of Years. He enjoys the Brightneſs of the Stars, and the Regularity of the Heavens: He is poſſeſſed of the Treaſures of the Earth and all its Productions. God ſeems to have given him even a higher Station, than that of being a bare Spectator of his Works, or even a mere Tenant of them. He has ſubmitted them not only to his Uſe, but to his Government. The Globe he inhabits is

covered with the Productions of his Industry and the Works of his Hands: The Improvement of the whole Earth is in Reality the Work of his Hands.

But, has he not Prerogatives still superior to all these? Let us not flatter or corrupt him by presumptuously bestowing on him those Attributes which he has no Title to. The Study of Man, and the Knowledge of his Privileges, are indeed worthy of us, but let us then ascertain them by the most authentic Records.

If he is no Usurper, if he disposes of all Things, because all have been submitted to him, it is plain, that the Study of his Privileges is but the Knowledge of our own Duty here. Could we then conclude our Enquiries into Nature, by making Choice of a more noble, or more interesting Subject?

But on the other Hand, the Study of Man is of immense Extent. The bare Disorders of his Heart fill whole Libraries. We must necessarily therefore, where the Matter is so fruitful, prescribe to ourselves some Bounds.

Whenever the most celebrated Writers have drawn us the Portrait of Man, they have wisely turned all their Thoughts on his Manners, from a Persuasion that they must first * reclaim him from Error, in Order to lead him to Wisdom. They have painted him with all his Vices, and represented him such as he is become by the Unruliness of his Desires. In this they have done him the most important Service. It is necessary to shew him his Faults, that he may blush at the Sight of them, and to make him sensible of the Depth of his Misery, that he may desire to extricate himself out of it. But the Success with which those skilful Painters have discovered or exposed his Weakness, and set before him the Disguises of his Self-love, will dispense with our taking up this Subject after them. It has been frequently enough placed in the strongest Light by the Heathens themselves, who have treated copiously on the Misery and Depravity of Man.

It will be of farther Service to him, to make him sensible of his true Greatness. He may, without flattering his Pride, be apprised of his lawful Advantages: And far from running any Danger, by unfolding to him the Titles

* Sapientia prima est
Stultitia caruisse. *Horat.*

of

of his Nobility, he will thence learn, without Precept or formal Lessons, the Knowledge of his Obligations, or at least the wholesome Advice of getting an Insight into them.

Such is the Light in which we are now going to consider Man. We shall, designedly, forbear searching into and censuring afresh his Imperfections. By separating the Work of Sin from the Work of the Creator, we shall survey Man as he came from the Hands of God: Or if we do not undertake to set him forth with that Brightness and Beauty he enjoyed in the Days of his Innocence; we hope at least, that, at the same time we turn our Eyes from his Defects, we shall bring him to draw a Comparison himself between his present Deformity and the precious Remains he still retains of his first Original, and to inform himself of the Means God has prepared for him of procuring his own Restoration. The Touches and Strokes imprinted on him by Divine Wisdom may indeed be altered, but not effaced; and it is his Happiness to be sensible of them.

Man cannot be ignorant that he enjoys the Productions of Nature, and that he is capable of giving Glory to the Author of them. He is actually placed between God and his Creatures. Every thing upon Earth pays Obedience to Man; but Man to God. By appointing him Master and Governor of all, God has a Claim to his Adoration and Gratitude. To this twofold Quality therefore of Governor and Adorer, I shall refer whatever can be said of Man; and pursue some Method which may help to fix our Ideas.

The Subject-matter of the V. Vol.

Man considered in himself.

Let us begin, by examining what Man is in himself, for what he is visibly appointed, in what his Excellency consists, and what he is capable of.

The Subject-matter of the VI. and VII. Vols.

Man associated with his Fellow-creatures.

From this entertaining Pursuit, we will follow him through his several Relations, and Dependencies on his Fellow creatures, that so we may see him concur with them in improving the whole Extent of his Possessions. Man thus considered, either in himself or in Society, will equally afford us Proofs of the Government for which God has designed him. This indeed was his Vocation

The Subject-matter of the VIII. and last Vol.

Man associated with God.

But, if he is appointed for something still greater, why should we make this the Bounds of his Glory? We shall see him enter into a Correspondence and Society with God himself.

This, my Dear Friend, opens a new Scene, and one far more interesting than the foregoing. We are ourselves concerned in it, as it takes in no less than all our Privileges and all our Hopes. But these Objects, so truly fit to affect a rational Mind, will have here the additional Advantage of not afflicting us with the Uncertainty of Disputes. We shall throughout drop all controverted Opinions, and keep constantly to the never-failing Advantages resulting from Experience. This Method of Procedure is above all things necessary in Matters of Religion. Revelation is the Work of the perfect Free will of God, who might have saved us by means quite different from those he has made Choice of. It is a Series of Facts, which Reason cannot find out of itself, and which it can never learn without the Assistance of external Testimony.

Although Faith be the Work of Grace in us, yet that Grace determines us to believe very rationally, and in Conformity to the Nature of Man, from sensible Motives, by Testimonies ever subsisting, by an immortal Embassy, which has been kept up with us for these seventeen Centuries, and which carries with it the obvious Proofs of a divine Legation. God is the Author and the Finisher of our Faith. But, whenever, for our own Comfort, or for the Confirmation of staggering Minds, we shall consider how far the Testimonies of Truth are credible, or how much the Unbeliever, who rejects them, is inexcusable; we shall find that it is not properly in Reason, but among Men that the Monuments, the Testimonies, the uninterrupted Legation, and the convincing Proofs of the Work of our Salvation are to be met with. If then I am able, as I hope I shall be, to convince you of the reality of the Records and Witnesses by setting them before you, what will become of the Arguments of Incredulity? They are no more fit to be read or listened to than idle Dreams. When we are shew'd by standing Monuments, and decisive Attestations, that God has done a Thing, what does it signify to us, that there are Men who say he ought not to have done it?

THE

Spectacle de la Nature,

The LAST PART;

Containing what regards MAN.

BOOK the FIRST.

Man considered in himself.

DIALOGUE I.

The Destination of Man on the Earth.

THE Historian of the Works of God is not contented with instructing us precisely how each particular Being was created, not by Motion, which can organise nothing; but, by the express Will and Command of the Almighty, which alone can give every individual Being its particular Structure, and convey Harmony thro' the whole: He teaches us farther the Use we are to make of Nature: He disposes us to direct our Studies and Actions agreeably to the Intentions of Providence, by shewing us the universal Design God had in View in the Œconomy of our Abode, I mean the Globe we now inhabit. The whole Purport of his Recital is to inform us of the twofold Design of God towards Man, which is to exercise him by Labour, and to perfect him by Religion.

After the celestial Orbs, and this our Earth were created; after the Light was made, and the Waters of the Ocean

Ocean ſeparated from thoſe which, by being volatilized, were carried far round the Globe; after the Creation of the Plants and Animals of all Kinds; the World appeared ſo magnificently adorned, that it might have been thought complete. But this Abode was ſtill imperfect, becauſe the Inhabitant, who was to take Poſſeſſion of it, was not as yet introduced.

The whole ſtock of Riches incloſed in the Globe, remained in its Boſom altogether unknown and uſeleſs. It was the ſame with an infinite Number of excellent Productions, which the Animals either could not obtain, or expreſſed the utmoſt Indifference for. Not only all theſe Preparations were ſuperfluous for want of an Inhabitant that knew or was willing to make uſe of them, but all Nature was beſides deſtitute of Sentiment and Gratitude. The Animals, which ſeem'd now to be the only Beings capable of ſome kind of Diſcernment, diſtinguiſh'd their reſpective Foods, without knowing the Hand that diſpenſed them; and the Author of ſo many Bounties was ſtill neither praiſed nor thank'd. The World was in a State of Imperfection, becauſe there was no Government by which the ſeveral Parts of it might be wrought, nor any Religion to give Glory to its Creator.

*Let us make Man in our Image, after our Likeneſs, ſaid then the Lord, and let Man have Dominion over the Fiſh of the Sea, and over the Fowl of the Air, and over the Cattle, and over all the Earth, and over every creeping Thing that creepeth upon the Earth**. The Earth, at laſt, has got a Maſter, and he is the Image of the ſupreme Being; as he is his Lieutenant there.

This Truth, the Extent and Conſequences of which we ſhall now endeavour to explain, has been preſerved among the Heathens themſelves. The Author of the *Metamorphoſes*, having brought the Creation of the World as far as that of the Plants and Animals, acknowledges that Nature ſtands in need of an Inhabitant capable of the nobleſt Sentiments, and of a more profound Underſtanding, and that a Maſter is ſtill wanting there †.

* *Gen.* i. 26.

† Sanctius his animal, mentiſque capacius altæ
Deerat adhuc, & quod dominari in cætera poſſet:
Natus homo eſt. *Ovid. Metam.* I.

Purſuant

Pursuant to the Charter which Scripture has preserved, Man now proves from Experience to be in Possession of all. The Heavens are in reality subservient to us, and the whole Earth is applied to our Use. If Philosophy is pleased to contest these our Prerogatives, we'll let her plead alone.

God was not only willing to make Man the Possessor and Governor of what is upon the Earth, but his chief Design was also to make him an Adorer, and a Being capable of knowing and honouring his Benefactor. *All is thine*, said he to Adam. * *Behold all the Trees of the Garden I have placed thee in: Of every one of them thou mayest freely eat; only thou shalt forbear eating the Fruit of such a Tree.*

This Reserve, which Unbelievers have made so many Complaints of, far from impoverishing Man, does, in Reality, constitute his chief Glory. Doubtless it is a great Honour to him to see himself appointed Master over every Thing that is Lifeless, and over every breathing Creature. All the Animals have already appeared before him. He has just examined in particular their Inclinations, Ways, and Industry. The new Inspector has given them all a proper Name, which is the just Expression of their peculiar Character or Operations; and whilst he sees all the living Species confined to some of the Productions of the Earth for their Food, or to one single Kind of Work for their Exercise, he finds himself provided with an Understanding which judges of all, which applies every thing to his own Use, and as well as his Dominions embraces the Universality of the habitable Globe. These Prerogatives are indeed very great and very flattering. But, here follows another that puts a still greater Distance between Man, and the Animals. The Discernment of the latter inclines them to feed themselves, and either to avoid Man with Fear, or serve him with Affection. If their Fear may sometimes be turned into Fury against him; it is because they are Slaves sensible of their own Strength, and transported with Passion: But the Prudence of their Master will soon know how to curb or prevent these Flights. However, all their Proceedings are confined to the present. The Body is the sole Object of whatever they do. None

* *Gen.* ii. 16, 17.

of them know their Origin, or Benefactor. [illegible] Testimony of Gratitude: Not the least Shadow of Religion. Man alone was raised so far as to know to whom he is indebted for every thing; he alone was taught to express his Gratitude for it. Sure, we shall not make his Glory to consist in a bestial Ungodliness, and an irreligious Stupidity. We indeed acknowledge his peculiar Advantage of being appointed the Tenant of this Earth: But it is an infinitely greater and more honourable Prerogative in him, to be able to please his Benefactor, and adore the Hand which loads him with Blessings. With regard to him whom God has appointed his Lieutenant on Earth, there is no Medium between revolting through Self-emancipation, and acknowledging his Sovereign through Duty and Homage.

The supreme Being stood in no need either of the Fruit of a certain Tree, or the Sentiments of man. But 'twas fit the latter should make an express Profession of his Gratitude and Veneration. Therefore, that sole Exception which God made, in his endowing Man with so extensive a Power, was at once the Memorial of his Gratitude, and the public Expression of his Piety.

We may even affirm, that if the Justice of this Reserve is self-evident, its indulgent Part is no less conspicuous. It was far more advantageous to Man to be subjected to, than discharged of this Acknowledgment of the Sovereignty of his Creator. Such an Exemption would have brought him back to the Condition of the vilest Animals, and exposed him to the Risk of becoming their Inferior through Pride, at Sight of his Riches and Prerogatives. But the Acknowledgment of his Subordination, that was so very fit to put him in mind of, and make him keep to his Duty, could never be restrained to any Practice that was less confining, or to any more easy Duty of Religion. Respectfully turning aside from the Tree forbidden to Man, was acknowledging, through the Privation of one individual Thing, that he enjoyed all Beings, though he had no Claim to any. It was publishing that he had a Master, though he ceased not to be a Master himself. God made Immortality the Reward of so easy and just a Religion. But he at the same Time forewarned Man, that the Minute of his first refusing the Homage, would forfeit his greatest Privileges, and give him over as well as the rest

of

of the Creation to the generality of the Motions through which the Almighty changes and renews all Nature.

If we ask the Philosophers what the Destination of the Earth and Man is; they will satisfy us with Doubts and Contradictions. But, let us but open the Book of *Genesis*, and it will inform us, that whatever is on the Earth was placed there for the Use of Man, and that he is born the Possessor thereof, on the bare Condition of publishing by one single Reserve, that he is God's Tenant for the whole. Such is the sublime Philosophy contained in the first Pages of Scripture: A Philosophy which makes the original Seed of Religion to consist in Gratitude.

But, on the other Hand, if this public Acknowledgment of the supreme Authority, is the very first Worship that was primitively required of Man, the Idea of it must needs have made a strong Impression on his Mind. This Testimony of a Religion ought to have been transmitted from *Adam* down to the Nations that descended from him, and the Footsteps of it ought still to be met with every where.

The Objection is most judicious. Let us then leave the History of the People of God, in order to consult on this Point the Ideas which all Nations have had of it. At all Times, and in all Places, Man, even when he mistook the Object of his Adoration, acknowledged his Vassalage and Dependence on the Divine Nature through some spontaneous Abstinence, or the public Offering of some particular Fruits, or other Productions of the Earth that were put in Reserve in a ceremonial, and remarkable Manner. This Homage paid to the Sovereignty of a Being who is the Owner of every thing, and daily supplies the Wants of his Creatures by a perpetual Renewal of all, has every where been the same, and always expressed by a public Consecration, though with some Variety in the Manner of it. Sometimes it was made to consist in respectfully abandoning the first Fruits of the Fields, or the first Spoils of the new planted Trees. Sometimes it consisted in consuming by Fire either the whole or Part of the fattest Beasts of Herds and Flocks: Or in laying on a Table, publickly erected for that Purpose, Bread, Wine, Oil, Salt, or other Elements of Life, in order to leave the Use of them to the Poor, or the Ministers of Religion.

And although the public Prayer was generally followed by a common Repast in Sign of fraternal Love; there was always a distinct Portion of their Foods which the whole Congregation forbore touching. By this speaking Action, they all acknowledged and thanked the Author of Life, for all Foods, Blessings and Favours. In short, the Expression of the Religion of all Ages, has from the Beginning been, as it still continues to be, a Profession of Gratitude*. This public Homage used by Men of the first Ages, which all upright Hearts have found so noble and reasonable, which in short was from its very first Original transmited to all Nations, even the most mistaken in their Manners and religious Practices, is exactly what the Lord required of the first Man. Thus the Heathens as well as the Hebrews, do by this first Ground of universal Ideas, equally point out to us the common Source from which they sprung, and jointly testify the Truth of that primitive Worship which is the Basis of Revelation.

* Εὐχαριστία, Eucharist, Thanksgiving. Ours is much more than the Acknowledgment of being intitled to nothing; as it is an Action that gives it to understand that we have Life only through him who was made a Victim for us.

MAN

MAN consider'd as Governor.

DIALOGUE. II.

SHOU'D we begin by conversing on the Work of our Salvation, and the Hopes which Man is called to; the Whole of what he possesses on the Earth might afterwards appear to us so very inferior to what went before, that the Study of it would on that Account become dull and insipid. Let us then reserve for the Matter of our last Works the Honour God has done to Man of accepting of his Adoration and Gratitude. Let us begin by the least of his Titles, even that of Governor and Master.

It is the Property of Scripture to represent the most sublime and most fruitful Truths with Simplicity, and altogether without Art; because it belongs to none but the Author of our Blessings himself to mention them cooly, and without Admiration. The first Instruction it gives us, concerning the Superiority that was granted to Man, proves to be in that very Order in which God made his Works.

He first fixes an Habitation. He then prepares all the Luminaries the Inhabitant shall stand in need of. He distributes through the whole several Kinds of Beauties and Conveniences, and assigns to a great Number of Servants their respective Places and Functions; and ends at last by introducing Man into it. This Order of Operations has nothing equivocal in it: And the Rest of the Lord, that is, the total Cessation of any other Work after an intelligent Being has been placed on the Earth, sufficiently shews us that it was for him that the Inheritance and Possession of all Things had been reserved.

But the Scripture has not abandoned this important Truth to the Uncertainty of our Arguments. It will not

permit that Man should lay a timorous Hand on the Riches with which his Abode is filled; but rather that he should use them with the Security of a Master who knows his own Lordship and Privileges. It clearly informs us of the Intentions of the Creator, in teaching us that God has made Man in his own Image, because he had destined him to command, govern, and order every Thing upon the Earth.

The Heap of Definitions, Researches and Dissertations, which the Philosophers have collected together concerning Man, do not by much come up to the profound Meaning of these few Words: *God created Man in his own Image*. It is rather a Word than a Discourse, made use of to make us conceive what it is our utmost Concern not to be ignorant of. It is but a Word: but all is included in that single Word.

The Manner in which God executed his Designs in this the very last of his Works, is a finishing Stroke which compleatly sets off the Excellence, and points out the primitive Destination of it. God did not create Man out of Nothing with a single Word, as he had done the rest of the Animals. He used a Mass of Earth to construct the Organs of his Body. He made of it a fine Statue, which he for a while left without Life and Understanding, and perfectly useless. Sure, this could not be the Image of God, it could never be the Governor appointed to rule over the Earth.

The Ram that bounds on the Grass, and the Stag that shoots over the Plain, are as yet more valuable than this motionless Lump. Nay, it might even as well as they be endowed with Respiration and Life, and be still inferior to them. They will almost all of them overtake it in running. Naked and destitute as it is of defensive Weapons; how will it avoid the Claws of the Eagle, the Jaws of the Lion, and the Trunk of the Elephant?

Every thing changes the instant God animates this Statue, and endows it with the Gift of Reason. What I observe in all the Animals is a Principle of Industry added to the Body, but solely confined to the peculiar Wants of it, and extending no further than the uniform Exercise of a few Organs, without any Hopes of Change or Perfection. It is not thus with Man. He has just received Reason;

son; and this alone provides him with every thing: It makes him acknowledge no other Superiority but that of the Creator, and by Means of it he exerts a real Supremacy over the Earth, both within and without, which invites him alone to examine and make Trial of the Whole. Take him out of it, and the rest are so much Riches thrown away.

When one says of a King, that all from one End to the other of his Dominions is submitted to his Government, the Meaning is not that the People are dependent on him for the taking of their Food, nor the Forests for their Growth, nor the Beasts for the Multiplication of their Species. Saying that *all* is subjected to him, means that he may make Use of and convey Order through all. Thus it is that Man is the King of Nature. It is his Happiness that the Fish should find their Food along the Sea-coasts, and all other Animals find theirs in the Fields, without his giving himself any Trouble, or using the least Precaution about it. Were he not discharged of these Cares, he would be overwhelmed with them. All Animals have been provided with Senses and Skill to conduct themselves. Regular and invariable Generations daily multiply the several Productions of the Earth. Man, without any Care or Trouble on his Side, finds these Riches continually renew'd for him. But he regulates the Use of, and has the Choice of either working them, or laying them by in Store. He pursues noxious Animals into their closest Retreats, and either exterminates or keeps them within Bounds. He diminishes the Number of those that might become hurtful: He increases and feeds whole Flocks of those he has need of: He tries all Things, and varies the Utility of them by giving them a new Form: Nothing, in short, escapes his Government.

Who has let go yonder Goats, which we see climbing the Hills, searching all Day long a few Blades of Grass, and then returning to him at Night, at the Signal he gives them? Was it not he that chose the Dog for his Lieutenant among the Sheep dispersed over the Plain? It is the Voice of Man that directs the March of Herds. He is heard commanding every where. The Roads, the Banks of Rivers, the Sea-ports and Towns resound with the Noise of the Beasts of Burden, that work under and for him. All, from

from the Top of the Mountains down to the very Bowels of the Earth, is full of rich Materials that wait but for his Commands, and will remain for ever in a State of Inertion, unless they are actuated by his Hand. All Sorts of Birds and four-footed Animals flock and croud round him, like so many Bands of Slaves always ready to improve his Estates, or lend their submissive Shoulders to receive his Charge and Loads. If it happens now and then, that a superior Force gets the better of his Desires and Cautions; if, for an Instance, an Army of Flies is sometimes stronger than him, it is because he has a Master, and it is proper he should be reminded of it.

Man is then born to govern. He that bears a Scepter, and he that wields the Shepherd's Crook, are like real Governors. Take but the Man that esteems himself the meanest of all: him who has made a Sacrifice of his Liberty, and who from a Fear of being left to his own Conduct, has given himself over to that of others: Shall we say notwithstanding, that he has renounced his Quality of Governor? Nay, had he but the Direction of a Door, the Care of a Kitchen, or that of the Linnen and Provisions of a Family; he still exerts his Foresight Patience, and Dexterity: he governs, he is useful and valuable, he is a Man. But he degenerates the Instant he ceases to be a Governor. Reason and Virtue become fruitless in him. He then sinks again into the first Condition of Man; and from that Moment is no more than a Lump of Clay, or, at best, a fine Statue, a vain insignificant Idol.

These Ideas, which are so much to the Honour of Man, very naturally flow, on the one Hand, from the two Words by which Scripture informs us of our Pre-eminence and our Resemblance to the supreme Master of all Things; and on the other they visibly agree with Experience, which submits the Fishes and Birds, the terrestrial Animals and the generality of the Productions of Nature without Exception to Man alone. But it does not suffice to lay hold on these Truths in a general Survey. It is by descending with Attention into the Particulars of the several Exercises of Man's Dominion, that we are to learn our own Rights, and the Manner of improving them to the best Advantage.

Here I find myself stopt by a Philosophical Scruple. If Man is a Mediator placed between God and Matter; if

he

he is obliged to give God that Glory which stupid Beings are unable to pay him; if he resembles God by his intellectual Faculty and Lordship, at the same Time that he resembles inferior Creatures by his Body; does not Order require that we should previously treat of the spiritual and corporeal Natures in General, that so, by the unfolding of these two Subjects, we may understand the better what Man is who reunites them both.

'Tis true that the Philosophers proceed very orderly in the Titles of the Matters they busy themselves with. One Book shall treat of the thinking Substance: Another will tell us what the Essence of Bodies in general is; a third will reveal what it is that constitutes the Association of Thought and Matter. Alas! how easy it is to range and order Promises! but pray, where is the Execution of these pompous Advances? What new Light or Benefit have we reaped from them? *Extension*, about which *Descartes* has made such a Rout, confounds the penetrable Extension with the solid one. And yet what a vast Distance there is between one and the other! Most likely the same which is between a Body, and meer rought. *Malbranche* was transported with the ravishing Lights he found in his intelligible Extension. Others, nevertheless, find it Darkness all over. We knew very well, before *Descartes* and *Malbranche* existed, that the Thoughts of the Soul were followed by the Actions of the Body, and the bodily Impressions followed by some Thoughts in the Soul. *Descartes* and *Malbranche* pretended that this Matter was not well understood, and that the essential Point consisted, in acknowledging that this Correspondence of the Body and Soul, subsisted by Virtue of an Order of the Creator, and pursuant to a Law established from the Beginning. That Law is a Word not made use of before them: But who was ignorant that the Thoughts of the Mind and the Actions of the Body, followed one another reciprocally by the Order of God? And what has this *Law* taught us more than a meer Word? And after so many Preliminaries and Debates on all those Questions, who is the Man among them that can teach us what a Body, a Brain, or a Drop of Blood is? Our Eyes are, still, as short sighted as before.

It

It is not with the Lights which we borrow from Religion and Experience, as it is with those which Philosophy promises us to no Manner of Purpose. The Scripture, 'tis true, does not methodically give us definitions, with both the Genus and the Difference, of what a Body and a Spirit are: A thing perhaps very unnecessary. But it informs us in the very first Pages, that Man is the Image of God, because he, like God, is to bear an universal Sway, and his Government extends to every thing on Earth. Nothing can be clearer, nothing more noble than this. To this first Truth the Scripture adds another immediately after, which is of equal Importance, and the natural Consequence, as it were of the foregoing, *viz.* that Man shall be possessed of all, on Condition that he shall publickly honour him that gave him all. Where could we find any Doctrine that was more affecting, more compendious, or more intelligible? There is no Mortal that does not understand what a Possession is, or is not sensible of the Justice and Reasonableness of Gratitude. 'Tis true, if you propose this to Philosophers, they, perhaps, will be divided on the Reality of the Possession and the Necessity of the Homage, or embarrass the whole by Arguments more obscure than the Thing itself. Some will tell you, that this Domain is an Usurpation. Man is an unprivileged Animal, and he ought not to raise himself one single Degree above the Ox or the Goose. Others will say, you are in the wrong not to acknowledge Man's Privileges: We'll challenge them by Virtue of the Excellence of the thinking Substance, and of the Ideas we have of the Divine Wisdom. Which intimates that they are going to employ Metaphysicks and Thoughts liable to much Controversy, to make us understand what is very simple, and what we all of us are sufficiently taught by Experience.

Philosophy will ask, if it is agreeable to the Nature of God to subject *Adam* to any Homage, and to order that, on his refusing it, he and his Posterity should become Mortal. Dictating the Decrees of God is no small Commission; and yet the Philosophers do not hesitate to take it upon them, as if they were appointed to let us into the Secret of them. Scripture and Experience do not say so much to us: but yet we may be contented with what they

say.

say. They reflect a mutual Splendor on each other. On the one hand, Scripture informs us that the first Worship required of Man was the Testimony of his Gratitude, expressed by an outward Acknowledgment of his having received all; and that the Denial of the Obedience of the first Man was punished by his Posterity's being subject to Death. On the other Hand, we find again in the Experience of all Ages, that all Nations have known the Necessity of keeping some of the Productions of the Earth in Reserve, in order to do Honour to the Divine Nature from which we receive them. Nor do we less experience the common Necessity of Dying, as a terrible Punishment which we are all doomed to undergo. Scripture, therefore, and Experience lead us to the very same Truths: and although they do not teach us whatever we may be pleased to ask them, yet what they inform us of is certain, and usefully instructive: Whereas there is no depending upon the Answers of Philosophy: And why should we follow it, if it may lead us astray? It will go further than we can possibly penetrate, and we ought to proportion our Researches to our Capacity. Now, we have at all Times and every where found, that we were clear-sighted enough not to confound one Thing with another, and able by Degrees to know the real Merit, the Use and Properties of Beings; but we have likewise experienced that we had no clear Idea whatsoever of their Nature itself. Let us here, of all Things, avoid running headlong into an Abyss of Disputes on the Nature of God and the Order of his Decrees, on the Essence of the Soul and that of the Body, and on the Nature of their Union. Let us be contented with what we can know of all this without Disputes and to some Purpose.

We know the Existence of God by the following Argument, which is as short and satisfactory as that whereby we demonstrate the Equality of the three Angles of a Triangle to two right ones.

There is some Being which exists from all Eternity, or the Beings we now see must have proceeded from Nothing: Which is impossible, since from Nothing Nothing can be produced. Now, that which has always been, either is an Almighty Intelligence that has ordered the World when and in the Manner it was pleased to do it, or it is the

the World itself, which both in great and little has ordered itself without any Wisdom or Design. But the World could not set itself in Order, nor establish a permanent Œconomy and constant Generations, without the least Intelligence or Design. Therefore, there must needs be an eternal Wisdom that has made all we see, when and in the Manner it was pleased so to do. We confess, that all the World is not capable of Reasoning; but without any Reasoning, we all of us feel the unavoidable Impression of a Power which controuls us, and an Intelligence which procures a Correspondence among all that surrounds us.

Next to God's Existence, we may study his Wisdom and Goodness; but, his Nature is inaccessible to our Reason.

We know our own Soul, our Desires, Joys and Thoughts, because nothing is more intimately present to us. Nay, it is our very selves. We know our Body, because we are tied to it. But, let us not needlesly rack our Brains, to know what the divine Nature is, what Thought, Life, penetrable Space, or solid Extension are; in short, what Kind of Tie it is that associates Mind with Body. Philosophers never cease turning our Thoughts that Way, whereas it is plain that we had quite another Task to discharge. For it is an evident and a punishable Obstinacy, perpetually to cast our Eyes upon what God keeps concealed under an impenetrable Veil: Whereas nothing is more prudent nor better rewarded than the Method of following the Light which God shews us, and of carrying as far as we possibly can that Discernment whereby he allows us to distinguish one Thing from another, and to learn how to bring the Use of them to Perfection. We stand in need of no more: And as we know Water sufficiently when we know how to distinguish it from another Element, how to boil or make it freeze, how to evaporate, thicken, or render it fresh, how to make it run smooth or spout out in what Quantity we please, without being able to say what that Water is; let us advance in like Manner in whatever it is possible and advantageous to us to know of God, of our own Soul and our Body, of our Duty, and of God's Designs in regard to us. It being evidently our Condition not to be ignorant of or acquainted with every thing: *Nec nil, neque omnia*; instead of turning our Eyes, and Re-

searches

searches upon the Nature of Beings, that is, upon the dark Side which Philosophers are so fond of, is it not more prudent for us to fix our Sight on the Part from whence the Light comes to us? Now, there are no Ideas either more luminous or fitter to elevate the Soul, nor any that cost it fewer Efforts, than those which offer themselves jointly both in Revelation and Nature upon the Dominion of Man. When it will be Time for us, from his actual Possessions to pass on to the Expectation of an happier State; we shall find again that Religion and publick Testimonies dissipate, by still surer and stronger Lights, the Doubts which proud Reason will affect to multiply.

MAN consider'd as GOVERNOR;

Proved from the Proportions and Excellence of the human Body.

DIALOGUE III.

IT being the apparent Design of God to make Man his Representative on Earth, whatever was bestow'd on him must be conducive to the Execution of that Design, and supply him with the Means of exercising an universal Power. The human Body, that of the two Parts of our Being which offers itself the first, was wonderfully framed for that Purpose.

The Anatomy of the several Pieces which compose the Machine of the human Body, is not what ought to occupy our Thoughts here. Although this Science be one of the most satisfactory, and perhaps that which has made the greatest Progress since the Revival of Sciences; its chief Object is the Dissection of the inward Organs, whereby the human Body agrees in its Functions with the Body of Animals; whereas our present Inquiry is on what distinguishes Man from Beasts, and enables his Body to master

ſter the moſt active and ſtrongeſt Animals. We want no Scalpelle, nor any Studies, to perceive, in the ſole Uſe of his Organs, the Exerciſe of a Dominion as extenſive as the Globe itſelf, and to be ſenſible that God has imprinted his Reſemblance on the Body as well as on the Soul of Man.

He that made the Eye, ſees without the Help of Eyes. He that made the Tongue, hears and makes himſelf heard without the Aſſiſtance of Speech. We ſhall not, therefore, look into the Form of the Organs for the Reſemblance of Man with God. That is the Part, on the contrary, in which he does not reſemble him. But the Impreſſion of the Image of the Almighty is found again in the Excellence of the Effects of theſe Organs. They are ſuch as render Man, in Reality, the Lord of Nature, beſtow on him the Activity of the Creator, and Rule over every thing on Earth.

In treating on the Nature of the Body and Soul of Man particularly, let us always remember that we ſpeak of a Body which is under the Tuition and Government of an Intelligence; and that the human Underſtanding is ſeconded and waited on by bodily Organs. When we admire the Skill of his Hand, we do not at the ſame Time forget that great directing Principle on which that Skill is founded: And when we admire the Science of that Creature who invents ſo many uſeful Performances, it will not be excluſive of the performing Hand. We ſhall only, for the Sake of proceeding regularly, give a more particular Attention to one of the Powers, and then to the other, but ſtill without rendering them independent. For, why ſhould we by any Means ſeparate what God has ſo ſtrictly united?

When we ſee in the Eagle voracious Inclinations, together with Claws and a Beak, fit to lay hold on his Prey, and tear it to Pieces, we judge with Reaſon, and without having Recourſe to the Diſſection of the inward Organs, that the Intention of the Creator was not that that Bird ſhould feed on ſmall Seeds, which his Beak can never gripe; or on a few Blades of Graſs, which could only diſguſt him. When, on the contrary, we obſerve the Inclinations of the Canary-bird and the Dove, together with their ſlender Feet and feeble Beaks, we aſſert, without the leaſt

least Apprehension of a Miſtake, that the Intention of the Creator was not that theſe Birds ſhould feed upon Blood and Slaughter. The Intention of God with Regard to the Lamb and the Lion is conſpicuous in the Tameneſs which retains the firſt near Man, and in the Fierceneſs which drives the latter into the Woods and Deſarts, to multiply their Species there, without aſking any thing of Man. The Horn which hardens the Horſe's Foot, and the Strength of his Hough, are Indications to us of the Travels and Services he will be fit for. We are never tempted to bite a Bit of Chalk, or a Piece of Marble, nor to employ the fruits of Trees in the Stone-work of our Walls. It is indeed in every thing, that the viſible Proportion which is between a Species or an Organ, and a never-failing Effect, ſufficiently informs us of the Deſtination of thoſe Bodies. We may then judge from the Inſpection of his Shape, from his Senſes, and from the Harmony and Concert of the Organs of Man in the producing a Multitude of Effects, that he is born to make uſe of all the Products of the Earth, and to put every Part of it under his own Direction.

Man's Head and Shape.

I. The Pre-eminence of Man is immediately declared by the Dignity itſelf of his Head, and the Advantage he receives from the erect Poſition of his whole Body. There is nothing ſo beautiful in nature as the Face of Man. The Tokens of his Superiority appear no where with more Splendor, though they are as really ſpread throughout the reſt of his Body.

His Features.

Majeſty dwells on his Forehead. The exacteſt Symmetry is obſerved in the Shape of his Face and the Harmony of all his Features. The Arches formed by his Eyebrows and Lids, at the ſame Time that they free the Eye from the Sweat and minute Elements that might tarniſh it, ſet off the Whiteneſs of it, and beſtow a new Beauty and Splendor on every Motion. It may be ſaid that Grace and Dignity meet and reſide on his Lips, ſince one ſingle Smile of theirs ſuffices to ſpread a Chearfulneſs all round them, and they give, thro' the Variety of the Sounds articulated by them, Orders which are immediately executed, or that will be carried to the greateſt Diſtances.

But

But the Perſon appointed to govern, ought not always to have Recourſe to Speech to be obey'd or underſtood, his Face therefore is the Mirror of his Soul. The rich Colours wherewith God has heightened the Beauty of its ſeveral Strokes, ſucceſſively expreſs either the Serenity of his Mind through their Calmneſs, or its ſecret Emotions by their ſudden Alteration. An unconceivable Multitude of ſmall Muſcles, and a ſtill greater Number of minute Strings diſtributed through them, terminate at his Cheeks, his Lips, and throughout the Extent of his Face, which form as many Expreſſions as there are inward Emotions. Some of them raiſe his Eye-brows, widen the Opening of his Eyes, and give him an Air of Statelineſs or Indignation. Others depreſs his Eye-brows, ſo as to rob us of the Sight of his Eyes, and, through the Multitude of the Plaits that furrow the lower Part of the Forehead, characterize either his Sadneſs or his Recollection; ſome of them are appointed to make the brighteſt Red, or the utmoſt Paleneſs ſuddenly ſucceed to his uſual Complexion, and by Turns to expreſs his Joy or Fears, his Approbation, Refuſal, or Deſpite, his Deſpondency or Security. Animals have ſome of the Paſſions of Man. But the vaſt Variety of the Signs which manifeſt them is peculiar to Man: For why is the open View of his Face ſufficient to let us ſee whether he is gay or ſad; whether he meditates, or is only relaxing his Mind; whether he threatens or careſſes, whether he is irritated, or pleaſed? Is it not to the End that his Fellow-creatures, and even the Animals, may be inſtantaneouſly informed of the Deſires or Orders of him who has a Right to be liſtened to. He would be diſgraced or fatigued by the perpetual Neceſſity of uſing Speech to make himſelf underſtood. His Thoughts are at once read in his Air, and at once he experiences around him Silence and Reſt, or ſuch Actions and Proceedings as agree with his own Concerns.

The Head, or rather the whole Man, reaps a mighty Advantage from the erect Poſture of his Body, towards exerciſing his Authority. All the Animals are reclined towards the Earth, and creep upon it. Man alone walks with his Head upright, and by this Attitude maintains himſelf in a full Liberty of Action and Command.

That

That Head thus appointed to regulate the Motions of the Body which supports it, and to watch over the Disposition of all the Products of the Earth, does not solely enjoy the Benefit of its own Situation and Dignity. It is the Seat of the Underftanding. It has exquisite Senses, and all the Organs neceffary to receive, Advices from, or send them to all Parts. Its Eyes ftand Centry in the higheft Story, and perceive at further Diftances. When the Eyes are taking their Reft behind the Curtain of their Lids, the Ears remain open, and are informed of every thing. It is oftentimes his Smell, that informs Man of what his Eye or Ear cannot tell him. His Tongue, befides the Faculty of diftinguifhing the Tributes which all the Earth pays him, enjoys the Privilege of impofing a Name to whatever is in his Habitation, and of difpatching all the Orders that are requifite towards the Management of it. That Head is vifibly appointed to govern, fince it is the only one that can keep a Correfpondence with the whole Univerfe.

The Character of the Motions of Man.

The Motions of Animals are, in each Species, confined to a Number fmall enough. The fame are repeated moft commonly, becaufe they all of them have but one Method which is peculiar to them. The Motions and Actions of Man are numberlefs, becaufe his Prudence and Operations were to extend to all.

If Man did, like the Quadrupeds, adhere to the Ground by both his Arms as well as by his Feet; he would from that Moment lofe the Multiplicity of his Actions. He would no longer be able to govern; and the Faculty of imbellifhing the Earth with feveral Works, could never be reftored to him but in Company with the Agility he receives from the erect Pofture of his Body and the Liberty of his Hands.

But, inftead of debafing him by making him creep with the terreftrial Animals, let us raife him up into the Heavens, and let him rule over all from that lofty Station. Let us fuppofe that his Arms are all over covered with long thick Feathers, and turned into a Pair of Wings. He begins to fpread them, and feeks the Skies. He cuts the yielding air, and his rapid Flight conveys him into the other Parts of his Abode, which he may vifit at his Plea-

fure.

ſure. Let us ſee now, if he is better ſerved by a Couple of Wings, than he is by a Pair of Arms. Does he gain much by that Change? He even loſes by it what he poſſeſſed before. His Arms and Feathers are an Inſtrument of Tranſportation: He never will ſpread them any more, but to fly: And that robs him at once of his nobleſt Privileges. If he leaves his heavenly Regions to come to the Earth again, he begins by ſtriking his Feathers; and in order to preſerve them from Filth, he gathers them cloſe to his Sides. Now he is perfectly lame and unfit for any thing whatever. Do but return him his Arms, and he re-aſſumes all his Talents and Riches. His Field will be ploughed, his Vine cut, his Foreſts felled, and his Proviſions layed up in ſtore. I ſee him from that Moment reaching thoſe very Arms into the Bowels of the Earth, and quite to the Bottom of the Seas, where his Wings were not ſo much an Help as an Obſtacle to his Undertakings. Ought not God, ſome Philoſophers will ſay, to have ſupplied Man with both Arms and Wings? My Anſwer is, that he has provided us ſtill better. We never ſaw the *American* Birds croſs a Space of two thouſand Leagues, in Order to come and pay a Viſit to thoſe of our Continent: But Man does in ſixty Days paſs from one *Carthagena* to the other. He, then, has better Wings than the *Tlanqueſhut* * and the *Toucan* †. When he ſhall have a mind to review his Plantations, or collect the Riches which *Peru* affords him, the Ocean, which is ſhut up to the Eagles, will not ſtop him. The Creator would not have Man be like a bird, becauſe he intended to make him a King.

The Proportion of his Shape with what ſurrounds him.

The Liberty of governing all, and of varying his Actions according to the Exigency of Circumſtances, is the firſt Help Man experiences from the noble Poſition of his Body. But the Analogy of his Shape with the Things around him, is a new Source of eaſy Methods to him in making himſelf Maſter of all. Had he

* A fiſhing Bird of *Mexico* and *Braſil*, which has a flat and very long Bill, that widens towards the End in the Form of a Spoon, like the *Dutch Pallet*.

† A Pye of *Braſil*, that has a Bill as big as its Body. See *Willoughby Ornithol.*

the Shape only of a Child, he could neither consume, nor even work the Productions of the Earth. A Gigantick Corpulence would expose him to Want, nor could the Earth supply him with all Necessaries.

Far from beholding with Envy Animals swifter than himself; he either makes them run for his Service, or borrows the Wings of the Winds and Seas, that transport him round the whole Globe. He wishes not for broader Shoulders in order to carry heavier Loads. He leaves tha kind of Glory to his Servants, as the Horse, the Ox, the Camel, and the Elephant. He need never complain of not being provided with Claws like the Lion, nor with Tushes like the Boar. It becomes the Lord of Nature to come unarmed into the World. Gentleness and Peace are his true Properties. But if he wants to defend himself, the Animals fly to his Assistance. Woods and Stones will oppose Walls to his Enemies. Salt, Sulphur, Fire, Iron, and all Nature conspire to shelter him from Insults.

He has indeed but an indifferent Degree of Agility, a moderate Vigour, and a middling Shape. Nevertheless, the Easiness of that Shape, and the just Constitution and Temper of his Faculties, cause him to be obeyed and served by the swiftest, the most vigorous and most formidable Creatures. We shall be still more sensible of this Truth, from a more particular Examination of a few of his Organs.

His Leg.

2. What we have just remarked of the whole Frame of the Body of Man, and of the exact Proportion between his Shape and that universal Sway which is allotted him, we may again observe in his Legs and Arms.

The Support of the Human Body.

At first Sight, the Leg of Man appears rather a fine Support than an Instrument of Activity. The major Part of Quadrupeds and Birds have in Fact an Agility much greater than that of Man. The former, being carried upon four Legs, support the Fatigue of long Journies better, and travel quicker than he does. The Birds, who, besides the Swiftness of their Feet, have the additional Help of Wings, enjoy a Liberty still more perfect. On the contrary, if we judge of the Legs of Man from their Structure, and from the Sole of the Feet which terminate

them, they appear Columns and Bases fitter to serve him a Support, than to facilitate his Travels.

He may, 'tis true, by Dint of Exercise, arrive at inconsiderable Degree of Agility. But that Nimblen which the *Grecians* admired in *Achilles*, and in their *A. letes*, and which may still surprize us in a running Fo man, or a Vaulter, is not the natural Privilege of M: Is it any Shame to him to be without it? Not a w more than not having his Fingers armed with crook Nails, or two of his Teeth stretched considerably out his Mouth, like those of the Elephant. Expedition running is the true Merit of a Messenger; and Man, say it again, is appointed to govern. But then his Le support him with an Air of Dignity, that sets him o and bespeaks him a Master. If they supply him som times with a commodious and speedy Conveyance, by the alternate Progression, it is only when he is to traverse sma Distances, or to carry his Orders and Cares to the Plac round him. But when he has a Mind to cross whole R gions, or overtake the Animals that fly from him; the indeed, he is served, and runs as becomes a Lord to do i Dogs of all Shapes and Skill, push through every Bush an Thicket, traverse great Plains, swim over Rivers, and, a his Command, rush upon the Game he pursues, or re spectfully bring back to him the Prey that fell beneath th Thunder of his Hands. The Camel, the Horse, the Ox the Rein-deer, and other Animals, equally useful by thei Activity, Strength, or Patience, successively offer them selves to help on the Culture of his Land, to transport hi Crops, and to carry him wherever he is pleased to go The Rivers bring him, from one Province to another, long Strings of Barks, each whereof is able to carry three o four hundred thousand Pounds Weight, and a great dea more. The Sea, in short, facilitates the Access of all Climates to him.

But tho' he is rather carried, than carries himself to these great Distances; his Leg, by a particular Form, and by Muscles peculiar to it, performs an infinite Multitude of Actions and Situations, suitable to the several Exigences of his Government, but useless and denied to his Slaves.

The Leg of Man grows less and less towards the Ground, where it terminates in a Basis flattened on Purpose to prop the

the Body by giving it a noble and firm Attitude, without clogging the Liberty of its Motions by the Largeness of the Bulk: And although the Beasts of Burden have their Legs made firm upon a flat Surface; the Advantage they reap from it as to themselves, is confined to the Solidity of the Position. Their Hoof is rough-hewn. It has neither Articulations nor Springs. But the Sole of Man's Foot being assisted by the Mobility of the Toes that border the End of it, and by the numberless Nerves as it were that spread and are dispersed in the Heel, and in the whole Texture of the Leg, supplies it with a prodigious Variety of Motions, both when Man has Recourse to them from the Necessity of his own Preservation; and when he is pleased himself to supply, or even mimick the Functions of the Animals that serve him. He does not always make use of the Horse's Legs, and he often is contented with imploying his own Activity. Sometimes he awakens all his Limbs by bounding like the Ram. Sometimes he gives a Spring like the Goat and the Chamoys, and with a Jerk shoots through the Passage he cannot set his Foot on. It is not uncommon with him to lay the whole Weight of his Body upon a single Foot, like the Stork: And, what is never seen in any other Animal, he balances himself, and affords several Postures and Situations of Body, though hardly supported on the Tip of one Foot only. He turns about on his Heel: He contrives a Multitude of Steps, some of which are grave, others quick and light: He unites them all, and makes them succeed each other in a Thread with Variety and Cadence, at once capable of delighting the Eye, the Ear, and the Mind, which are always fond of Symmetry. He most usually neglects these Efforts, the chief Merit of which consists in the Difficulty of the Execution, and contents himself with that Part of Dancing, which may procure the Ease of his Motions, or set off his natural Dignity, not much caring to reckon among his Talents the Caperings and Grimaces of the Ape, or the impetuous Motions of the Grass-hopper.

Dancing.

The Muscles and Nerves which produce so many Stretchings, Retractions, Jerks, Slidings, Turnings, and Operations of all Kinds, have all been collected in one

Bundle, neatly rounded behind the Shin-bone. This mass becomes a commodious Pillow, fit to lay and rest that tender Bone upon, so very necessary, and so brittle. It is at the same Time a Rampart to it, against the Blows and Injuries it may be exposed to on that Side where the Eye cannot prevent them.

The Calf of the Leg.

The Extremities of all these Strings come down cross each other quite under the Sole, or stop in the Way, and stick to the several Parts which are to bend or turn, according to the particular Impulsions. Two strong Carnosities, like a Couple of tough horny Cushions, cover the Under-part of the Heel and the Tip of the Sole; that the Weight of the Body resting upon them, the Vessels that lie under them may not be strained or deprived of their Action; and that the Middle of the Sole forming a concave Arch somewhat raised from the Ground, it may admit there, as much Air as will spring against the Pressure of that Arch, and always dispose Man to some new Motions.

I pass by a great many other marks of Precaution this Instrument is evidently full of: but, I must not omit observing that the two Columns of the Body, always go up thicker and thicker, not only to lay the Body upon a proportionable Support, but also that it may lie soft, when it wants to ease itself of its Fatigues. The Arm and Hand together contribute still more to the Exercise of the Authority of Man.

The Arm and Hand together.

3. Since Man has an Arm, I says he is Master of every Thing on Earth. This must naturally follow. That being truly the Token and the Instrument of a most effectual Sovereignty. Behold the Animals. One is born a Hunter, and has the Instruments fit for Hunting. Another is born a Fisher, and it is in order that he may reach very deep into the Water, that he has both his Neck and Beak very long: He has also a Pair of long scaly unfledged Thighs, that he may dip into the Water without soiling himself in the Mire. The Vocation of another is to carry or draw Burdens; to which Purpose his Hams and Shoulders are wonderfully adapted. All have their proper Functions,

Functions, together with the Tools belonging to them. They all have a Trade, in which they respectively excel: But no more is to be expected from them. You may perhaps with Blows, Inticements, or Exercise, break them to some less common Operation, and oblige them to vary their Motions according to your Desires, and the repeated Signals you give them: But all that Skill resides in yourself, and argues no particular Dexterity in them; much less is it the Mark of any Design of theirs, or of the least Degree of Perfecton acquired by Reasoning. In short, all their free Operations are as limitted as the Instruments of their Profession: But the Arm of Man being an universal Instrument, his Operations and Government extend as far as Nature itself.

That Arm, by stiffening, performs the Functions of a Lever or a Bar. When bent in the several Articulations that divide it, it imitates the Flail, the Bow, and any Kind of Spring whatsoever. By doubling the Fist that terminates it, it strikes like a Mallet. When it rounds the Cavity of the Hand, it holds Liquids like a Cup, and transports them as a Spoon would do. By bending or joining its Fingers close to each other, it makes Hooks, Pinchers, and Nippers of them. The two Arms stretched out imitate the Balance; and when one of them is shortened to support some great Burthen, the other stretched out immediately on the opposite Side, constitutes an Equilibrium, and, like the *Roman* Balance, makes up the Overplus of the Weight with the Length of the Leaver.

But comparing the Arm and Hand with those of our ordinary Instruments, is extenuating their Merit. In the exactest Truth, the Arm is both the Model and the Soul, as it were, of all Instruments whatsoever. It is the Soul of them, as the Excellence of their Effects does always proceed from the Arm and Hand that direct them. It is likewise the Model of them: Since they are all so many Imitations or Extensions of its different Properties. That Arm, which by stiffening heaves up a Stone or a Piece of Timber, has given us the Idea of the Leaver. It lengthens itself in a Manner by laying hold of that Leaver. Its Strength may thus be increased a Hundred-fold, and more, and then it turns over a rough Piece of Marble, or makes a Heap of Trees it has cut down move before it. That

Arm, which could give alone no indifferent Blow, and which raiſed, no doubt, the firſt Idea of all Hammers, by cloſing up the Fingers, when it comes to borrow the Aſſiſtance of a Mallet or a Club, knocks down an Ox at one ſingle Blow. It pulls down Oaks from the Tops of Mountains, whence Man drives them partly towards his Habitation, or to the Places near his Vineyard, or to a River's Side, according as he wants to prepare a Roof, a Preſs, or a Bark.

The Hand of Man may alſo carry and tranſport Fire and Liquors, ſtir up the Earth, lay hold of Wood, Stones, or any other Body: but it performs all theſe Actions only in little, often with ſome Diſadvantage, and at the Riſk of being burnt or bruiſed. A Senſe of the Services it offers him, and of the Dangers he expoſes it to, raiſed in him the Idea of Helps. Spoons, Nippers, Pincers, Shovels, Spades, Pitch-forks, and all Tools in general, are ſo many Hands which imitate in great what the Human kind does in ſmall. It ſkreens itſelf from being hurt, by offering them in its Stead: and what its natural Tenderneſs hinders it from executing by itſelf, it performs with Advantage by the Shape and Solidity of the Tools it is capable of managing.

That Hand, ſo very weak to Appearance, that Hand which would be but faint, or even bruiſe itſelf, if it ſtruck immediately upon Stones and Metals, needs but direct a few Pieces of Wood or Iron towards maſtering all Things, and rendering them uſeful by a juſt Correſpondence.

That Arm which is not two Cubits long, and but four or five Inches broad, performs Wonders when aſſiſted by the Vigour of the Tools which repreſent or defend it. It ſeems then that nothing can reſiſt or ſtop it. It bruiſes vaſt Rocks, and breaks thro' Mountains. It reſtrains Rivers, and forces them to run in new Channels. Iron and all Metals take what Turn it is pleaſed to give them. It conquers the Reſiſtance of Marbles and Stones: It ſhapes them at Pleaſure like a Piece of ſoft Wax; and now makes of them as an Arch to join the two Sides of a large Canal; now whirls them about into a Stair-caſe, to render every Part of Man's Abode acceſſible to him, or lays them abreaſt and in a String, from *Rome* to *Brunduſium**, to

* The *Via Appia.*

make

make them become in the Middle of the muddiest Plains, a Way as hard as Iron itself; a Road that shall be passable, and frequented after two Thousand Years Service*.

But the Hand of a Man, perhaps, meets with so much Success only when it acts upon Matters void of Sense. What contradiction does it not experience from Animals? This Resistance, far from disgracing the Hand of Man, infinitely heightens the Merit and Value of it. The Hardness and Weight of Marble and Metals was never any Dishonour to the Hand which overcomes them. How does it compass the hewing and fashioning a rough Piece of Marble, so as to make a noble Figure, a light Drapery, the Features of *Lewis* XV. come out of it? What it could not attain to by itself, it performed by the Assistance of the Mallet and Chisel. How did it dare attempt to raise and hang up a Bell of thirty Thousand Pounds Weight an Hundred Feet from the Ground, or to terminate the vast Pediment of the Colonade of the *Louvre* by an Ogee of two Stones only? It called to its Help, Levers, Pulleys, Wheels, Cranes, and all Sorts of Machines, in which a very small Force gets the better of a very great one. With these Helps the Hand of Man makes itself sure of the Victory over what resists it, and it is that kind of Magick that constitutes its Glory, by infallibly subduing the heaviest and most unmanageable Matters. The Fierceness of wild Animals, which serves to people every Part of Nature without the Intermission or Cares of Man, does nevertheless not hinder the Hand of Man from putting them under the Yoke, and making a Profit by them whenever there is Need. 'Tis true, it is weak, and could not resist the Tiger's Teeth. The Elephant would bruise it with one Blow of its Trunk; and if it attempted to bridle the Camel's Head, it would not be able to reach it. It is that very Hand, nevertheless, that confines both the Tiger and the Lion. It is that which makes the Elephant pass from one Region into another. Nay, it will, at its Pleasure, drive a numerous Herd of them from *Spain* into the very Heart of *Italy*, as it would drive a Flock of Sheep from one Pasture into another. But, if it meets the River *Rhône* in its Way, how will it do to encourage the Animal frightened

* See *Misson's* Voyage to *Italy*.

at the Sight of an Element unknown to him, or how will it be able, with ſuch a reſtive Maſs, to overcome the Rapidity of the River? It will firſt prepare a Raft, and cover it with green Turf: Then it will introduce into it ſeveral Elephants together, as if they were paſſing from the high Road into a Meadow: And then with a few Tuggings of an Oar, it puts the whole Meadow in Motion, gets it off one ſide of the River, and conveys it to the other with as much Eaſe as it would carry a Roſe, or a Sparrow. The Hand of Man tames the Bear which comes and kiſſes it; and ties up the Camel that bends his Knees to receive the Fetters, or take upon him the Load it has prepared for him. Far from diminiſhing the Encomiums of the Hand of Man, we ſhall complete them the more, by ſaying that it cauſes itſelf to be ſeconded every where by a Force which is not its own; that it employs Matters which exiſted, and were made before it; that it has the Skill to take Advantage of the Proportion which is between the Weight of the Water and the Lightneſs of Wood, to charge Rivers with the greateſt Weights: That it makes up its own Inſufficiency with Tools and Counterpoiſes, and by the Acceleration of the Motions it finds throughout every Part of Nature. There indeed lies the Wonder. Things inanimate, the ſtrongeſt Animals, the moſt immoveable Weights, the moſt determinate Motions obey it ſoon or late; all is ſubordinate to it. It not only ſoftens the Roughneſs of the fierceſt Animals, but it makes their very Paſſions and Violence ſerve its Purpoſes. Its Dexterity turns every thing to its Profit: And although that Hand is of itſelf ſomething very ſmall, although it has produced nothing it makes Uſe of; yet when we caſt our Eyes upon its Victories and Productions, we might be apt to take it for the Hand of the Almighty.

But the Philoſopher, who values his own Thoughts better than thoſe of Scripture, and who has formed the noble Project of humbling Man, by robbing him of all Reſemblance with God, will, after all this, perhaps affirm, that though the Hand of Man ſeems indeed to diſtinguiſh itſelf in ſome Works that have an Air of Uſefulneſs and Grandeur, ſuch as a Palace, a Ship, an Arſenal, a Sea-Port, theſe are but a few bold Strokes which it may have been introduced to make by Neceſſity: But ſhall we ſtill find this

vaſt

vast Resemblance between God and Man, when we descend to the small inconsiderable Works with which he most commonly busies himself? Is he not disgraced by Trades that require no Force nor Industry, such as Spinning and Sewing? One half of Mankind is contented with these despicable Operations.

The Art of Spinning, far from deserving this Insult, is perhaps of greater Value than the Occupations of the Philosophers that pass this Judgment. Here they may be beaten with their own Weapon. They all of them extol in their Metaphysics such Causes as produce very great Effects with little Apparatus. Thus they think it proper, by one single Law of Motion, which they call very simple without understanding it, to produce both Man and the Mushroom, the Structure and Propagation of which they are still less acquainted with: That is indeed producing a great deal at a very small Expence. Let us now apply their exquisite Rule to that Art which is the Object of their disdain. Two or three Fingers pinch the last Threads of a Pack of Wool, Silk, or Cotton, of a few Flocks of Wool, or of some fine Rinds of Trees hanging up at the end of a Reed. The same Fingers, after having twisted and thickened these Threads into one, tie the End of it to a slight Piece of Wood, at the lowest Part whereof they fix a small Circle of baked Clay that will be removed when the Spindle is grown somewhat heavier by being charged with a greater Mass of Thread. That Wood being rolled gently between the Fingers of the right Hand, communicates the same Turn to the Thread that sticks to it, and disposes the Twists that are still separate to apply to one another, from the Necessity of turning all the same Way. The Extremities of the Twists that come next prove to be perpetually intangled with the first that hurry them away with themselves. They all advance forward, and twist on the same pace under the Fingers of the Left Hand, that pulls and presses them successively, Next to this, the Right Hand winds round the Spindle the Thread formed by the Left; and both Hands alternately repeat these their respective Functions: Such is the Simplicity of the Operation.

One might here very justly praise the Skill and Exactness that makes this Thread so perfectly even. One might

ask with a well grounded Amazement, how the Fingers of an *Indian* Woman can possibly feel and uniformly govern a Thread which the Eye can hardly perceive. Let us not, however, dwell any more upon a Work that requires so very little Effort: It seems not that human Industry can receive any great Honour from, nor Mankind reap any Benefit by it.

But it is the very Simplicity and Easiness of this Work that will constitute its greatest Merit, if any considerable Benefit can result from it. We have already conversed upon this Topick, and it will be sufficient here to repeat, that it is those Twists and Threads, or some others of the Kind worked in a Manner still more expeditious with the great Spinning-Wheel*, that will serve by their Union to form all the Weavings and Textures that can be imagined, from the Rope and the coarsest Girth, down to that kind of fine Muslin, which, when spread over the Hand, will shew nothing but the Hand. It is therefore this kind of Work that supplies us with Attire and Furniture of all Kinds. It affords us the Strings, without which we cannot join together or govern any Thing. It gives us the Cord, which, when stretched out between the two Points of a Bow, will dart a killing Arrow into the Body of the Wood-hen, or the Pheasant. The same Work will prepare Bonds for all terrestrial Animals, and form those Nets that make Man bear Sway to the very Bottom of Rivers and Seas. He is indebted to that very Work, for the sounding Lead that directs his Course upon an Element that retains no Impression of the Passage of the Travellers that went the same Course before him, and for the Sail that brings him the Productions of both Hemispheres. We are then entitled to say, that the Art of Spinning invests Man with his Demesn; and thus the most insignificant of all Works will set in the brightest Light this Truth; that Man was born to govern, when he was endowed with Arms and Fingers, even though he were to employ them merely in making a Piece of Cloth.

We lavishly bestow our Admiration on certain Fingers, that shew their Agility on the Theorbo, or the Harpsichord.

* See *Vol. VI. The Article concerning Manufactures of Wool and Cotton.*

chord. But the Fingers which we despise, because they can only spin, deserve rather our Respect and Gratitude. What would become of us, if the Ladies should take it into their Heads to give over the Arts of Spinning and Sewing, in order to get a Name, as our systematical Philosophers do, or pass their Life in frivolous Murmurs, like our grumbling Metaphysicians? A strange Occupation this! The many Complaints they make of Providence, the Attractions, the Monades, the Vortexes, with which they are fond of racking their Brains, did never procure us the Enjoyment of one single Inch of Ground that was useless before. The commonest Kind of Work, on the contrary, is the first Support of all our Enterprizes, and visibly makes good the Promise of God to Man in the Scripture, of submitting every Thing to his Authority. Thus the Hands of the Ladies do more Honour and Good to Mankind than the Heads of a great many Philosophers.

If, next to this, we pass on to the several Works that forge our Iron, that build our Houses, that make our Clothes and Attire; we every where perceive new Degrees of Perfection: but, as we need not, for the present, run over every one of them, it will suffice to inclose them all in one Remark common to the whole; *viz.* That in every thing that comes out of Man's Hands, the Generality of the Effect points out to him the Generality of his Dominion. Let us again mention one or two of his less toilsome Operations. I see his Hand making a few slight Strokes with a black Liquor upon a piece of Paper. That Paper carries Demands or Orders as far as he pleases; and a few Lines (the Work of two or three Minutes) may perhaps establish a Correspondence between two People absent from each other, at never so great a Distance, or reconcile two Families on the Point of going to Law about the Property of an Estate that was disposed of some Centuries ago by an Act now contested between them; or it will perhaps cause the two Extremities of the Globe to concur in the Execution of one and the same Enterprize.

The Stomach of Man.

4. These last Relations, in consequence of which a Man brings about at *Batavia*, or *Vera-cruz*, a thing resolved upon at *Amsterdam* or *Madrid*, will, perhaps, make some People fear that we mistake Greediness, and mere acts of

Usurpation, for a lawful Dominion. Instead of saying to Man, as Scripture does, that God has submitted the Herds Flocks, and Birds, the Fishes, and all the Treasures of the Earth to him, would it not be much more prudent to humble him, by reproaching him with his Thefts, and the odious Liberty he allows to himself of disposing of every Thing from one Pole to the other?

With the Scripture before their Eyes, bad Philosophy can proceed from nothing but bad Maxims. Why will Philosophers preach not only in Presence of the Scripture, and without following Experience; but even upon Principles opposite to both?

When we have a mind to humble Man, we should not do it by accusing him falsly. The Power we reproach him with is no Crime. The Possession he is in, and Use of every thing, is no Tyranny. It is the visible Work of the Creator: And taking from him what God has given him, to put him on a Level with the Oister and the Snail, is by no means humbling, but downright degrading him to a Brute.

Those, who have made Complaints or Satires on the Liberty Man takes of using whatever the Earth produces, knew not, or only pretended not to know, that the Things appointed for the Service of Man are sanctified by his Prayer, and by the Moderation of the Use he makes of them. On the one Hand, those Declaimers do not perceive that this vast Consumption made by Man is strictly connected with the immense Provisions, that are fit for none but him, and with the constant Renewal of the Productions of Nature: But do they not, on the other Hand, feel at the Bottom of their Hearts, without any Metaphysicks or Disputes, that it is Man's Thanksgiving that constitutes the Correspondence of the whole Creation with its Author? * Take Man away from the Earth, and you'll make it at once useless, and without Harmony.

After having heard those clear Instructions which the Scripture and Experience jointly give us upon that Subject, we may, without any manner of Risk, make use of Arguments and Reasoning. We may know the Destination and the general Power of Man in the same Manner we

* See *the Letters that close the First and Third Volumes.*

know

know the peculiar Deſtination of the Eye or Leg. The Proportion of theſe Inſtruments with certain Effects, points out to us the Intention of the Creator. The Proportion of what is within Man, with what ſurrounds him, is a perfect Indication of the Generality of his Power. Thus the Hand proves to be made not only to ſerve him, but alſo to employ and work every thing on Earth, becauſe nothing but that Hand can reach and rule the Uſe of the whole. It is the ſame with moſt of the Organs of Man. They ſerve him; but all the Earth helps them to ſerve him, and all the Earth is acceſſary to their Operations.

One might be apt to think that his Stomach confounds him with the other Animals, ſince they all have a Stomach, and digeſt as well as he does. But, although Man is diſtinguiſhed from them becauſe he was placed on the Earth for ſomething elſe than barely to digeſt, yet his very Stomach ſerves to evidence his general Dominion.

The Cormorant, the Plungeon, and the Hern, have a Stomach fit to digeſt the Fleſh of Fiſh. But then you will always find them ſeeking for their Food upon the Banks of Rivers and Lakes They never were ſeen obſerving, as the Dove does, the Departure of the Plowman who has juſt been ſowing his Ground. The Lion and the Tiger have a Stomach fit to digeſt the Fleſh of terreſtrial Animals. You would in vain tie them up to the Rack or Manger, and reduce them to a few Oats, or to the Graſs of your Meadows. The Horſe overlooks the Hen that turns up the Straw he treads upon, and never covets the few Grains of Corn which ſhe picks up, as they chance to be ſhed from his Mouth. The Cow, which, by the Weight of her Foot, ſometimes forces the Worms to come out of the Earth, never lays any Snares for the Sparrow that comes full Speed up to her, and greedily thruſts his Bill into the Ground, to carry off that Prey which he is not ſtrong enough to force from its Shelter. The Beaſts of Burden, who exhauſt their Strength for our Service, are no leſs valuable on account of the Cheapneſs of their Food: And in vain ſhould we attempt to reward their Labour by offering them Meats of the moſt exquiſite Taſte, which they would turn away from with Diſguſt.

The Animals are then, from the very Diſpoſition of their Stomach, tied down to a certain Kind of Food. But Man

Man is confined to nothing; and as he has on his Tongue the Discernment of all the Savours divided among the Animals, he has likewise in his Stomach the Faculty of digesting whatever is good and nourishing. The Air, the Water, and the Earth are equally at Work for him, and every Year renews a Variety of Foods, many of which are known and useful, or even accessible to none but him. The Shad and the Sturgeon, which seem to seek him out, in passing, as they do, from the Sea into the Channels of Rivers, fear neither the Wolf's Jaw, nor the Hern's Beak. And the Oyster, which by opening offers the Dog an easy Prey, is nevertheless sheltered from his Insults, and exposes the Invader to a dangerous Mistake.

If certain Animals, which are but few, and most of them but of small Size, as the Dog, the Cat, the Parrot, and the Sparrow, can equally live upon the Fruits of Plants, and the Flesh of Animals or Insects; this is in order to procure the Consumption of the most useless Remnants, and to set Bounds to the Multiplication of certain Species. All these Appetites and Structures of Stomachs are Works varied according to the Views of a Providence which takes in all, which foresees every individual Inconvenience, and knows how to remedy it by wise Precautions. Who will dare to blame that Providence for having made the Life of one Species to depend upon the catching of Fish, that of another on the Use of the Flesh of Animals, and that of a third Kind on the Pulp of Fruits, or even the Production of a single Plant? It would be equal Rashness to criticise on those Reserves and Distributions, or to find Fault with the Universality of our Appetites, and to style the Contributions, which every Element pays to the Stomach of Man, Tyranny and unlawful Usurpation.

But Metaphysicians will cry out, It is a Shame to exaggerate in this Manner a Dominion full of Injustice, and to insist so strongly upon Prerogatives that are uncertain, at the same Time that you affect in every Respect to extenuate the noblest Privilege of Man, even his Reason. You will have it confine itself to what it can learn from Experience and Revelation, the latter of which you even look upon as making a Part of common Experience. It is keeping Reason in Swaddling-clothes. How can that Reason acquire any Vigour, so long as you keep it im-

prisoned?

prisoned? Let us free it from all its Confinements, that it may take Wing and soar upwards; we shall soon find it capable of every thing. Oh! how happy Men would be, if we could but persuade them to espouse our Notions! At least we may make them blush at the Sight of their own Excesses. The Domain which they assume to themselves requires a most ample Reformation. Let us try to bring this about by wise Regulations. We do not pretend to reduce Man all at once to too severe an Abstinence. We will be contented at first with demanding one single Point; for Instance, *we shall make it a Law to him never to touch any Kind of Fish whatsoever.*

This first Regulation is made with more Zeal than Knowledge. The Fishes we are speaking of do not find their Food in the deepest Waters, nor in the most rapid Streams. The greatest Part of them live upon Butterflies, which fall at certain Times into their Abodes, or upon Gnats that chuse to live near Waters, in order to lay their Eggs on them; or they feed upon those small Worms and innumerable Insects that swarm, for the Service of Fishes in the Mire, along the Sea-coasts, in Creeks, under the Projections of the Roots of Trees, or of Rocks, in every Out-let and Ditch, and generally in all Places where Water stagnates, or is almost standing. The watery Insects disperse throughout these Retreats, where Fishes come to seek for them. But since the publishing of the Law that forbids the catching of Fish, those Creatures multiplied so prodigiously, that the shallow Places where they resort, far from affording them the Quantity of Food they stand in Need of, can neither contain, nor even cover them. These Waters, when diminished by the Return of the Heat, leaves whole Heaps of Fish on the dry Ground; and their Fruitfulness becomes pestilential and fatal to us.

Men must remedy this as well as they can; they must fly from the infected Places: But Injustice ought not to be a Means of making them live easier. Let us go on with our Reformation, according to the Notions of the all-wise *Pythagoras*, and the *Brachmans* his Disciples. Let us do nothing by Halves, and to the Law that forbids the eating of Fish, let us add another, to prohibit, without any Mercy, the Use of whatever proceeds from terrestrial Animals.

Fleeces

Fleeces ſhall, for the future, clothe no other Creature but the Sheep they belong to. The Milk of the Cow ſhall not be eaten but by her little One. The Egg of the Hen ſhall not be taken from her. Man ſhall leave Slaughter and Blood to the Lion. It behoves the Animal endowed with Reaſon never to touch the Skin, or invade the Liberty of thoſe that have not an equal Reaſon to defend themſelves from him. Flax and Cotton ſhall ſuffice to ſupply him with Clothes. Let him tye a Piece of Board under his Feet, to preſerve them from Hurt. If he is moderate enough to confine himſelf to the Uſe of Plants, he will have what Food, Lodging, and Clothes he ſtands in need of.

Let us now ſee the Conſequences and Effects of this pretended Reformation. We obſerve in the voracious Species of Animals, ſuch as the Wolf and the Bull-Dog, a Singularity not void of a Deſign on the Part of the Creator. The Male is angry at the Fruitfulneſs of his Female; and foreſeeing, as it were that this Teemingneſs threatens him with many a dreadful Rival, he endeavours to rob his Female of her Whelps, and then tears them to Pieces. We ſhall find the Fecundity of Birds of Prey ſtill more limited, both from the Difficulty of ſupplying their Young with Food, and from the perpetual Dangers with which their warlike Manner of living is attended. Providence hinders the dreadful Species, though uſeful in ſome Reſpects, from becoming hurtful by an exceſſive Multiplication. Nothing, on the contrary, more fruitful than domeſtick tame Animals. The Hen, the Dove, the Goat, the Ewe, and many others, but, in particular, thoſe whoſe Fleſh is good and palatable, are eaſily fed and brought up.

The Animal, which is fit to nouriſh none but working Country-people, may bring forth twelve or thirteen young Ones at a time, and make us the ſame Preſent thrice in one Year. Now if domeſtick Animals multiplied ſo much when they were killed freely and every Day, what muſt become of them for the future? Ever ſince the Publication of the Law that debars us of eating the Fleſh of Animals, or of uſing them as our Property; they no longer know the Bridle, the Hook, or any other Rule. The Fields, now open to them, are quite full and overcharged with them. Our Crops and Fruits are more theirs than

ours.

ours. The Ewe, incredible! becomes our most dangerous Enemy: She scorns the Grass of the Fields, and as long as she can find any Ears of Corn, she pretends to enjoy the Advantages of the fine Season, and all the Sweets of her Independence. Nay, we must not even flatter ourselves with being able much longer even to share them with her. Being now destitute of all Power over the Liberty and Life of Animals, and reduced to the Service our Arms can do us, we can no longer take their Clothes from them, nor procure any to ourselves, nor even cultivate our Grounds. The latter are as much their Patrimony as our own. What Title could authorize us to appropriate them to ourselves? The deserted Countries are now covered with Briars and Brambles Anarchy and Confusion render the Earth a frightful Habitation: All is void of Rule and Culture upon it: There is no enjoying any thing there with Security, because every thing has been rendered common: And in Consequence of this new Reformation, Man is sufficiently happy if he can prudently support himself by sharing with the Swine the Mastage of the Forest.

If then Man does not feed merely on Bread and Acorns, but also upon every good Thing God has created; he does not do it because he has usurped any thing, but because God has indeed given every thing to him. God is the Author of the Privileges as well as of the Wants of Man; as well of those Things that would have attended his Innocence, as those that are the Punishment of his Crimes. He sends him hither with Hunger and Thirst, with Dangers and Diseases, and destitute of Clothes and Weapons: These are all his Wants. But he gave him Senses, that he might quickly discern what is good, without even consulting his Reason. He gave him Hands, that he might lay hold of and fashion whatever can nourish, cure, or defend him; he gave him a Stomach capable of digesting the Foods tried by his Palate. Thus, totally naked and destitute, Man was provided with every thing by the Creator. God has shewed him the Proportion he had established between his Organs and all that surrounds him: He has determined him, by Necessities of every Kind, to the Exercise of his Faculties. He has therefore appointed him full Possessor of the Earth; and it is his Dominion alone that can maintain in it the Order which Anarchy would

would infallibly overthrow. But, we ſhall ſee in its proper Place, that God, at the ſame Time that he raiſed Man to the Glory of reſembling him by ſo honourable a Seignory, has moderated the Uſe of his Faculties by means of his Conſcience. The ſame Experience that made Man ſenſible of his being upon Earth to poſſeſs it, has informed him that he ſhares this Lordſhip in common with other Men: That he cannot even enjoy it without their Aſſiſtance, and that they have all of them the ſame Privileges as himſelf, ſince they are equally the Images of that Being which governs all, and are equally endowed with Underſtanding and Power.

It is indiſputably evident, that as the Lion, from viewing his own Claws, is acquainted with his Power, and is ſtopped or reſtrained by no Law whatſoever; Man likewiſe, by the Knowledge of his own Faculties, and his own Conſciouſneſs, knows what his Privileges and his Obligations are. He cannot poſſibly be ignorant of them. It is equally true, that as the Power of the Lion is confined to terreſtrial Animals, becauſe God has ſhut up all the Avenues of the Air, and the watery Main from him; the Power of Man extends to the Birds and Fiſhes, becauſe God permits his Hand to reach them. Let us ſay all in a Word. The Power of Man is as extenſive as his Faculties and his Abode. Therefore his Domain is univerſal, and it never degenerates into Barbarity, but where the Contempt of his own Conſcience makes him a Monſter inſtead of a Man. Thus we ſee the perfect Agreement of Experience and Reaſon with the Scripture.

Reaſon goes aſtray on no other Account, but becauſe it will either go firſt, or even walk alone. Whence it happens that the *Indian* Philoſopher has a Reſpect for the Blood of a Fly, while the *Braſilian* drinks up that of his Fellow-creature.

But if Revelation is not heard among theſe Nations, Experience and their own Conſcience ſpeak to them at leaſt. Both inform them, that Man was made to rule over the Earth, but that all his Fellow-creatures ſhare the ſame Dominion with him; whereas the Animals are ſo many Inſtruments and Proviſions which God animates and multiplies for our Uſe, and which would throw every thing into a general Confuſion, if we might not lay our Hands

upon

upon them. The Voice of Experience, and of our Conſcience, has then taught us at all Times, that the Virtue of Man does not conſiſt in abſtaining from every Thing, notwithſtanding his being ſenſible of his own Privileges; but in making Uſe of every Thing with Moderation and Juſtice.

It muſt be confeſſed, however, that notwithſtanding the uniform Inſtructions Man every where hears within and without himſelf, his Reaſon, blinded by his unruly Deſires, and fond of being its own Guide, would, in many Things, be given over to Darkneſs and Uncertainty, to dangerous Delays and fatal Miſtakes, if Divine Revelation had not come to his Aſſiſtance. Reaſon is not our firſt Rule in point of Manners, and in the Uſe of our Faculties, any more than in the Determination of revealed Truths. It follows the Rule, but does not make it. Its Glory and Tranquility, both in its Conduct and its Belief, conſiſts in being ever the Diſciple of Revelation. If we had been educated among the Cannibals of *Terra Firma*, or the Man-eaters of *Braſil*, a long Habit, together with the acceſſary Idea of compleat Power, would make us find a Shadow of Juſtice and Pleaſure in what muſt cauſe in other Nations nothing but the moſt horrid Loathing, and the total Revolt of their Heart, their Reaſon, and their whole Being.

This Inhumanity, the Conſequence of Pride and Anger, ſeems to have been univerſal before the Flood. One may judge of the Diſorders that are reigning in a certain Age, from the Nature of the Laws which they give Birth to. God had given *Adam* a full Power over the Bleſſings of the Earth, and the Animals of the three Elements. *Cain* buſied himſelf about the Culture of Fruits, and *Abel* with feeding of Flocks: 'Tis likely they both lived upon theſe Things, as they both teſtified their Gratitude for the ſame, by reſerving for the publick Offering the fineſt of Fruits, and the fatteſt Beaſts of the whole Flock. This is the Beginning of the Dominion and Adoration which have continued ever ſince.

God, far from giving *Noah* a Power more extenſive than that he had given to *Adam*, gave him the very ſame Prerogatives he had granted to the firſt Man, *viz.* the free Uſe of terreſtrial Animals, of Fiſhes and Fowls: But he did

did it with a Restriction. When he permitted *Noah* to use the Flesh of Animals, he forbad him, at the same Time, to eat the Blood of them. What could be the End of this Reserve? It aimed at stopping that Spirit of Revenge and Ambition that feed with Delight upon the Blood of a conquered Enemy: An execrable Custom! that was always renewed in Places removed from the Body of Society. In short, there was no surer Precaution to render the Blood of Man respectable, than a Law that caused the Blood of Beasts themselves to be respected. In the universal Depravation which Idolatry had introduced into the World, the same Law was perpetuated in the Nation which inherited the Promises. Before the Grace of our Saviour came to reform the human Heart, the Law required, above all Things, an Abstinence from Blood, because the Virtue of these transitory and altogether cautionary Laws, consisted in containing Families within the Bounds at least of the outward Worship of the true God, by deterring them from Vengeance, Inhumanity, and enormous Crimes.

But if a useful Polity was at least procured by that means, why then has the Gospel, the most perfect of all Doctrines, abrogated so wise a Law? It is because Prohibitions and Precautions are perfectly needless to hinder the *Christian* from feeding upon the Blood of his Fellow-creatures, since he is taught in the School of Grace, not only to love his Fellow-creature, but also his Prisoner and his Enemy. Nothing is more secure than what we love, and that single Article shews us, that the Law of *Noah*, that of *Moses*, and that of *Jesus Christ*, are the Work of a Wisdom which takes in all Ages without Exception.

The Mouth.

5. The Stomach of Man is not the only Part of his Body that seems, by its Functions, to have a near Affinity with that of the Animals, at the same Time that it has a Degree of Excellence that raises it much above them. It is the same with the other Organs of Man. Let us, in the handling of so fruitful a Subject, be contented with the first Reflexions which the Structure and Operations of his Mouth naturally raise in our Minds.

What a Combination of various Cautions and Operations is it! Vast Praises have been bestowed on *Torricellius*, *Paschal*, *Guerric*, and *Boyle*, for having observed the over-

powering

powering Pressure of the external Air upon what does not contain any other Air or Fluids capable of resisting that Pressure. They are looked upon as the Fathers of modern Physics; because they have led us through Experience to many Truths never perceived before, and fruitful in Consequences, by either inventing or improving such Machines as (by the Substraction of the Air contained in them) presently evidence the full Force of the ambient Air, destitute of a Counterpoise. What these great Men have executed with so many Praises on our Part, is still more wonderfully effected by the Lips of a new-born Infant. They apply themselves to the Breast of the Mother, without suffering any Air to enter into the Mouth. The Lungs attract to themselves the Air that was contained in the Mouth. The Tongue, by its Contraction, occasions a Vacuum which is not filled by any new Air. The Air, which from the whole Height of the Atmosphere does then exert its Pressure upon the Nurse's Breast, finds no Resistance in the Orifices of the Nipple surrounded by the Lips; so that the Milk must needs be forced out of the Breast, and rush into the Mouth of the Infant. Very often his little Hands will, without any foregoing Instruction, second the Action of the Air, and hasten the Assistance.

As the Lips are the Rampart of the Gums, the latter are the Fence of the Tongue and of the Roof of the Mouth. The Gums are a Couple of true Bulwarks shelving at the Foot, and rounded into two Platforms making a Semicircle, not only to form an exact Inclosure round the Tongue, but also to serve as a Basis to the two Rows of Teeth, which have their Roots very deep in them, and there disperse a Multitude of small Vessels through which the Teeth receive their Life and Nourishment.

The Teeth.

These Instruments, chiefly appointed to grind and dissolve, are of a bony Substance, and perfectly hard. But as the Function of these Bones is important, and their Work incessantly repeated; they have been covered over with an Enamel harder still, which imbellishes the Mouth by its Whiteness, and preserves those precious Tools from the Friction of massy Foods, and the Insinuation of penetrating Liquors.

The eight *Incisores.*

The incisory Teeth fill the forepart of the Mouth, and are Four or rather Eight in Num-

Number, since there is a double Row of them, on Account of the double Jaw. They are thinner at the End like a Wedge, and as sharp as Knives, that they may bring to a convenient Shape the Quantity of Food which the Mouth can contain and dispatch.

The Two Canine Teeth.

The two Canine Teeth which accompany the four Incisores, one on the Left, the other on the Right, are rounded longer than the rest, and end in a Point, that they may break and cut up what is fibrous and capable of Resistance.

The Twenty Molares.

All the Teeth that come next, and are together, sometimes Sixteen, but more commonly Eighteen or Twenty in Number, have a square Surface that grows wider and wider, as the Tooth is deeper in the Mouth. They are called *Molares* or Grinders; because when the Upper-teeth apply their Surface against that of the inferior ones, they visibly appear to be appointed to grind. The Effect of this Disposition is to render the Trituration finer in Proportion as the Meats advance under wider Grinders, and draw near the Point at which both Jaws being united, have, on that Account, the strongest Action.

The Incisores, which offer first, cut out what shall be the Task of the others. The Canine break through every thing, and fashion the Work. The Grinders pulverize the whole, and by a sufficient Mastication completely spare the Stomach the Overplus of the Work it must have with Pieces barely quartered.

All these Pieces, though totally void of Intelligence, yet do nothing blindly, but, on the contrary, unanimously work for the same Purpose. What can be the Wisdom that guides them? Is it that of Man? But he is commonly served without knowing the Artifice of this Preparation; and the Understanding of the most skilful Anatomist has no manner of Share in it. Here, as well as in any other Case, the Goodness of the Instrument is a great Relief to human Reason: But the Superiority of the latter is still maintained, since it was left to its Sagacity to try and improve every Thing by Coction, by proper Mixtures, and a just Seasoning.

The Tongue is not a Muscle, but an amazing Assemblage of various Muscles joined together. It may in an

Instant,

Instant, and without any other Preparation than the bare Desire or Intention of the Person that uses it, successively lengthen, shorten, swell, grow sharp, round, flat, or stiff; it may bend, turn about a thousand Ways, and beat now against the Roof of the Mouth, and now against the End or the Root of the Teeth, and make Motions with a Volubility in many Respects superior to that of the Tongue of the Nightingale.

The Salivary Glands.

It is bordered, especially about its Root, with Glands full of a Water somewhat salt and saponaceous, which being squeezed out of them by the Motions of the Tongue and Jaws, runs into the Mouth at Work, and helps on the Deglutition.

At the very Root of the Tongue begin a Couple of Pipes laying one above the other, called the Oesophagus, and the Trachea. The first of these Ducts takes in the Drinks and Foods, and conveys them into the Stomach; the other, which is more internal, as it lies under the Oesophagus, conveys the Air into the Lungs in Inspiration, and conveys it back in Expiration. As soon as any thing but Air enters into the Trachea, either coming from without, or by Expectoration, it experiences an immediate Tremor which shakes all the cartilaginous Rings it is composed of; and then it makes an Effort to free itself from that strange Body by a Convulsion which is called Coughing. One can hardly conceive, that notwithstanding the Danger of letting the least Body whatsoever fall into the Trachea, the Creator has nevertheless placed above the very Orifice of that Canal the Mouth of the Pipe through which all our Victuals and Foods are to be conveyed in o the Stomach. But, by an Artifice, the Boldness whereof is worthy of the great Author of all Mechanics, there happens to be at Top of the Trachea a small Draw-bridge that rises for the passing of the Air in and out of the Body, and is let down so as to shut exactly the Orifice of the Canal at the very Instant that the minutest Particle of eitheir Solid or Fluid offers at the Oesophagus. What constitutes the chief Beauty of this Precaution, is, that the least Quantity of Food imaginable presses, in its going down, the Nerves of the lower Part of the Tongue, whose Action is always followed by the Bridge being let down upon the Trachea, before the Food or Drink can reach it.

But

But these Wonders, which no one can have so much as a Hint of without being amazed at them, are as much multiplied throughout the human Body, as the very Organs of it are, that is, altogether innumerable. The Anatomists observe them to the best of their Power, they assign Names to them, they know the Action of those that are most perceptible, and dispute upon the Use of the rest, but they at the same Time confess that the Structure of all is, to any strict Enquirer, an Abyss that swallows up both our Eyes and our Reason.

However, if this Structure, which has a great Affinity with that of the Body of the Animal, was perfectly unfolded to us, we should not, however, make it our Topick here; as the Plan we have laid for our Rule is to establish a Resemblance of God in Man. In what then does the Mouth of Man shew him to be appointed to preside over every Thing on the Earth?

The Voice.

The human Voice, which we have not yet mentioned, seems to be but little fit to promote our Design, since the Animals have a Voice as well as Man, and one cannot ascribe a Mouth or Voice to God, otherwise than in a figurative Sense. 'Tis true, the Birds, the terrestrial Animals, and many Insects have a Voice, Cries, Hissings, or Hummings, which they make Use of to inform one another, and which they vary to express their Anger or Content, their Alarms, or the Acquisition of what they like. But the Variations of their Voices are as much confined as their Concerns and Relations. Speech, on the contrary, puts an immense Distance between Man and the Animals. There is nothing in Nature but what the human Voice can express by so many Articulations or Inflexions. Man speaks of every thing, because there is nothing that is not, in some Respects, submitted to his Judgment or Authority. Speech, which extends to all the Objects in the Universe, and their several Uses, does then declare the Extent of the Prerogatives and Rights of Man: And it not only places the Animals very much under him, but even makes him the sole Images of God upon the Earth.

The Merit of Speech does not consist in Noise, but in an Universality of Signification. Man can express his Thoughts very variously. *Philoctetes*, when he shewed

with

with his Foot the Place where the Arrows of *Hercules* lay, doubtless was unfaithful to his Friend, since he had promised him never to tell where he had deposited them. Now, if making one's self understood is the same Thing as speaking, we may of course speak with the Foot, the Eye, or the Hand. A Man who seems transported with Joy, or overwhelmed with Grief, has already told us many Things before he opens his Mouth. His Eyes, his Features, his Gesture, his whole Countenance correspond with his Mind, and make it very well understood. He speaks from Head to Foot: All his motions are significant: His expressions are as infinite as his Thoughts, and we have sufficiently observed in another Place, that his Signals, his Tokens, Writing, and various Monuments, extend to all Places, and deliver down his Intentions to remotest Posterity. But his Voice takes the Place of these Signs whenever he pleases: And it is not only equivalent to them, but even sufficient alone to give to understand very distinctly what they cannot express when combined together. It is the most pliant of all Instruments, and the prodigious Variety of the Sounds, with which it strikes the Ear, makes it the most convenient Means to form a Series of Signs, and connect a Series of Thoughts with them. The Monuments of the Birth of a Child, that was appointed to be the Lord and Saviour of Mankind, may from Age to Age fill up the Thoughts of Minds intent upon distinguishing their Meaning and Purport. But a Minister of the Gospel, who is at the Head of four thousand Parishoners, may, all at once, and by the single Motion of his Mouth and Lips, collect in their Minds the several Proofs of that Birth, and there awaken all the Sentiments it naturally inspires us with. He at once transports his four thousand Auditors near eighteen Centuries higher back than the Moment in which he speaks. They are now going to be one Company with the Prophets, the Angels, the Shepherds, and the *Magi*. All of them are moved, or at least acquainted with the Excellence of their Vocation. Such is the Power granted to one Man, to one single Tongue. It has the Privilege of fixing the Attention, and working upon the Hearts of the Multitude, of turning their Thoughts upon God and his Works, upon past and future Things, upon their own ill Conduct, and their true Interest and Concerns.

Man makes himself understood in a thousand different Ways, and Speech was superadded to all these Signs, that he should not want any Means of explaining himself clearly. But in this Privilege, which Man alone enjoys, of communicating his Thoughts to all about him, to those who are at a Distance from, and those who shall come after him, who but must discover the sole Image and Representative of God upon Earth! God does in reality speak throughout all Nature, nor was it made for any other Purpose but to declare his Intentions. We should in vain say to a Man, that we intend to do him Good, if we did not fulfil our Promises; but when we do him a piece of Service on an urgent Occasion, that Service speaks for itself: our Friendship is truly eloquent, and the Man is fully sensible of our Love to him, without the Assistance and Interpretation of Compliments, and verbal Protestations. All that we have already observed of the *Spectacle of Nature*, and all the other Things still to be subjoined to it, are nothing but a Series of Bounties, an instructive Order, a Chain of everlasting Testimonies and Monuments of this great Truth. All Nature is then the Voice of God, and the Expression of his Will. Who has not heard the Voice of the Heavens? In what Place does not God speak to all Mankind, and to every one in particular? He addresses himself to the most wicked, and declares his tender Love for him, by letting his Sun rise upon him as well as upon the good Man, and by making him Copartner of the Just in the free Use of his Favours. Wisdom cries aloud; its Voice is distinctly heard in the Silence of Retreat, as well as in the Assemblies of the People, who mutually communicate its Gifts and Instructions to each other. It is heard upon the Mountains, which it covers with useful Forests for our sake; and in the plains, where it yearly renews those Crops and Harvests by which we are fed. It is heard upon the Waters, through which it has opened us a Way, and in the Bowels of the Earth, where it prepares for us Stones, Slates, Metals, and all the Matters that are fit either to cover or supply us with Furniture. Man is then the Image, and the sole Image of God on the Earth, since he is the only Creature on it, that can judge of and express his Mind concerning every thing.

Here

Here is another Particular that ſets off the Excellence of Speech. In the Silence and Quiet of the Night, which aſſiſts me in comparing the Univerſality of the human Speech, with the Univerſality of the Language of God, my Ear is ſuddenly ſtruck with delightful Sounds: I hear a grand Chorus of ſolitary Men ſinging in my Neighbourhood*. The Signal that calls them together is hardly over, but a loud ſonorous Voice addreſſes them in the following words: "O come, let us ſing unto the Lord, let us make a joy-"ful Noiſe to the Rock of our Salvation." The Chorus anſwers this Invitation; the Voice begins again, and I hear them ſinging on by Turns in the ſame Strain.

Singing.

Two new Advantages offer here at once, both of which can give a ſtill greater Splendor to the Merit of the human Voice; the firſt is the Prerogative of ſpeaking to God himſelf, and the other that of adding the Sweetneſs of Melody to the Uſefulneſs of the Signification.

This might, perhaps, ſeem the propereſt Time for us to point out what Share the Body takes, by means of Speech, and by the Union of many Voices, in the Worſhip which Man is bound to pay to God, both for himſelf and in the Name of all his Fellow-creatures. He ſpeaks to God as a Friend ſpeaks to a Friend. It is the ſame Confidence; it is the very ſame Effuſion of Mind; and God, far from taking any Offence at ſuch a Familiarity, is, on the contrary, never offended but at our Silence. But it is much better, for the preſent, to lay aſide the immenſe Subject of Religion, than to mention one Part of it ſeparately, without treating of the reſt. Let us then be contented with only conſidering in the human Voice, that amazing Pliantneſs, which, after having ſupplied the Expreſſion of all our Wants, ſtill affords a Melody capable of aſſwaging our Toils, and of entertaining us in our Solitude.

In every thing Man alone unites the Prerogatives that have been granted but ſingly to any particular Species. He poſſeſſes them all, and, by their Re-union, enjoys them in a much ſuperior Degree. Birds fly indeed; but Man navigates, and this is a great deal more. All Animals

* The Author has lived a great many Years, and lives ſtill by a Convent of Monks, at *Paris*.

transport themselves from one Place to another: Man alone enjoys the Privilege of causing himself to be carried. Several Species sing; but their Singing is stupid, or altogether void of Signification. The Melody of Man alone is an intelligible Language that charms the Ear, that fills the Mind, and is heard by God himself.

The Charms of Singing.

Next to the ordinary Use of Speech, which consists in signifying our Wants and Intentions, it is a great Comfort to us, to be able to procure to ourselves, by means of the same Voice, the Delights of sweet Melody. The Attractives of it are so very great, that the most perfect Instruments, with which we support the human Voice, are always inferior to it. Some of them are dull, or hardly audible; others are harsh, or speak as it were through the Nose. Many will give none but instantaneous, Sounds, without Continuance. Several of them will afford uninterrupted, but at the same time inflexible, cold, uniform Sounds. Those, which have a very full Sound, are apt to bellow; those, that have it very loud, are either shri l or squeaking; and their Defects can never be concealed but by being drowned in a grand Concert. A fine Voice, on the contrary, is a continued, pliant, delicate, or rather inchanting Sound. It is the finest of all Sounds, as well as the sweetest, and it is a Pleasure experienced by the Ear, but not to be accounted for by Reason, that Sound alone has that peculiar Merit of being susceptible of all imaginable Tunes and moving pathetick Notes. Properly speaking, there is no other Sound in Nature that has a Soul in it.

But, whether you are willing to give a peculiar Attention to the noble Harmony which is produced by the Union of several Tones and Voices, or overlooking the Beauty of the Agreement of Sounds, and are more particularly affected by that ravishing Melody which results from the Inflections and Judgment, whereby a Song is adapted to the Subject, or the Passions of the Mind; in both Cases, that Song never ceases to be a Language, or else it would be unworthy of Man: Now, every Language ought to be intelligible, since we never speak but to be understood: The Melody assumes to itself the Turn of the Passion and Sentiments of the Singer: It is a delicate Imitation of their Character: But it still has a Respect for the greatest Prerogative

rogative of Man, even that of thinking, and of expressing his several Affections. The Sound, which proceeds from a lifeless Instrument, may, as well as the Notes of the Nightingale, amuse our Ears for a few Moments; but, the Sound, produced by the human Voice, ought never to be void of Meaning; otherwise it degenerates into an Absurdity. It is even that the Meaning of a Song may please and affect more strongly, that we add to it the Symphony of a Series of delightful Sounds. If that Musick is so much clogged with Ornaments, and runs divisions with so much Swiftness, that the Meaning of it can no more be understood, it is no longer what we call the Voice of a Man. It is the Noise of a Machine combined with many others; and in that Case you see nothing but a Multitude of open Mouths, shining Teeth, and quavering Lips, very busy about telling you nothing.

MAN consider'd as GOVERNOR;

Proved from the Excellence of his Senses.

DIALOGUE IV.

IT is the Business of the Anatomist, learnedly to demonstrate by the Enumeration, Sorting, and Assemblage of the Organs of the human Body, the Wisdom of those Precautions that facilitate its Action, and assist it in the exerting its Superiority over all the Animals. As for us, we ought to be contented with fetching our Proofs from what can be offered to every Eye, without any Apparatus or Study. Such is, for Instance, the Excellence of our Senses. They are the true Ministers of our Knowledge and Sciences, and it will not be improper to enquire into the exact Value of them, especially after the many Efforts made by the Moderns to discredit them.

God, whether he is willing to lead us to Salvation, or communicate to us the Knowledge and Use of created

Things, always instructs our Reason by the Mediation of the Senses. But the Philosophers cry out: Never listen to your Senses; but to Reason, and Reason alone. That will teach you every Thing; which will lay all Nature, and the very Order of the divine Decrees, open before your Eyes.

These Promises are frivolous; and whenever the Philosophers have attempted to proceed in this Manner, which is not that of God, they never brought us to any Knowledge that was either sufficient or satisfactory. A Reason that will walk alone, and never takes any but metaphysical Steps, is a Reason either actually wandering, or ready to go astray: Whereas it advances from Truth to Truth, and bears a most real Sway over all the Earth, when, according to the Institution of the Creator, it walks in Company with all its Senses, and informs itself, through their Ministry, of what it can afterwards either govern or improve by Means of its Discernment.

Ask a Man born blind, what Colours must shine in the Heavens when he turns his Back to the setting Sun, and a few Drops of Rain are falling on the opposite Side. Such a Man, though never so judicious, is a perfect Stranger to Light and Colour: He understands neither the Refraction nor the Necessity of the Return of certain Rays into his Eyes. Nor will he tell you of the *Iris*, but what he knows of it on the Testimony of his Ears. But the Ear, being not appointed or framed to judge of Colours; his Reason remains helpless in that Respect; and, whatever it may pretend to conceive of the Beauty of the Rain-bow, will be little better than a Dream.

Present to *Descartes* a Pine Apple freshly cut off from the Stalk, and perfectly ripe. Desire him to examine the inward Frame of that Fruit which is but just begun to be cultivated in *Europe*, and from that bare Inspection to tell you what the Taste of it must be. We have a Right to demand every Thing from a Reason like his, which comprehends and accounts for every Thing. This Reason was strong enough to fetch out of the Idea of homogeneous Matter, primitively put in Motion, the Generation of the World, and the true Structure of the Planets and Stars: It has seen Man, the Animals, and all living Creatures, distinctly proceed from the same Matter; and its knowing the Cause in the most distinct Manner, argues the Necessity

ſity of its knowing likewiſe the Structure of the Animals and Plants, which are only the Effects of that Cauſe. It will then be an eaſy Matter for *Deſcartes* to determine the Mechaniſm of the Germen of this Ananas, and to tell us before-hand what peculiar Taſte and Qualities it muſt needs have. No, *Deſcartes* will never find out that Savour in his Reaſon, nor even in the Concurrence of the Elements and Veſſels of the Fruit itſelf, after having analyſed and diſſected it: His Palate alone can and will let him into that Secret. But, if his Reaſon proves altogether helpleſs, when from the Structure of a Body which he ſees and diſſects at his Pleaſure, he is to deduce the Neceſſity of ſuch and ſuch a Taſte; what muſt his Attempt be, when he preſumes to recount the Generation of the Sun, and to tell us, the Sun is this or that, and nothing more? He indeed knows much leſs of it than he does of our Ananas.

The *Newtonians*, who, like *Whiſton* and others, have attempted to conſtruct the Planets, and by Attractions and Calculations, to account for whatever paſſed in them; do not give us a better Idea of their Phyſics, ſince they are equally at a Loſs, and ſtopt ſhort by as inſignificant a Subject as the Savour of an Ananas they never taſted of.

Stball, *Beker*, and all the Chemiſts, may, with their Diſſolvents, find more Oil, more Salt, more Earth, or more of certain Principles in the Ananas than in another Fruit, and they will be ſtill indebted to the Eye and Hand for that Diſcovery: But they never will arrive, any more than we, at finding out the Taſte of that Fruit, otherwiſe than by having Recourſe to the Senſe appointed to judge of it. The Inſpection of the Reſidues remaining after the Analyſis gives the Chemiſt no manner of Right to foretell whether that Fruit will be wholeſome or hurtful. Experience, as it has often been the Caſe, might contradict the Prophecy; there being Spirits, and other Principles, which are either carried away or altered by the Fire, and in the Soundneſs or Union of which conſiſts the Goodneſs of the Fruit.

Here is now a Set of Naturaliſts that go to work in a quite different Manner, in order to arrive all at once at what can be found out of the real Value of the Ananas. They ſcorn to throw away their Time, in recurring to Generalities imagined by Reaſon, and which never caſt the

least Light upon any particular Case whatever. They first put the Fruit in their Mouth, which is immediately overflowed with a delicate Syrup, and is a great while after still affected with a Perfume which embalms it. They then presume so far as to guess that this Fruit will be wholesome, and the Prediction is justified by Experience. It is then the Province of our Taste, primitively to tell us, in Conjunction with Experience, whether a Fruit, hitherto unknown to us, will, or will not be a wholesome and pleasant Food. This is the right Philosophy.

It is the same with any other natural Body. Let that of our Senses, to which it may have a Relation, be what it will, we shall judge of it by that Sense. Our Reason cannot pass any Judgment upon it without Temerity; the more so, because after having informed itself of that Body by its Senses, it cannot give the least Hint concerning it, to such as are either destitute of the Organs proper to that Kind of Discernment, or not placed within the Sphere of Activity of their Senses.

We might, instead of one Example, alledge ten thousand, which will equally demonstrate that human Reason ventures a great deal in attempting to walk by itself, and behaves very prudently, on the contrary, and answerably to its Condition, when it waits for and collects the several Advices of its Senses, which are the Instruments of a constant and universal Instruction to it.

Let us take Care, however, not to run headlong into Mistakes here, by enslaving our Reason. For if it can make Discoveries without the Assistance of the Senses, is it not just to assign a certain Province for Reason, and a peculiar District for our Senses? Do we not disparage that sublime and penetrating Reason, by making the Certainty of the greater Part of its usual Learning to depend upon the Testimony and Experience of its Senses? If they had been given us to instruct our Reason, and enable it to act, would they be so imperfect as they are? We know no more than the Outsides of Objects by means of our Senses: And when we enquire into the Principles of Bodies, or the Structure of the small Vessels, or the Action of the minutest Organ, these Things prove altogether inaccessible to our Senses. We must repute as an Insult done to Reason, the Words of that Member of the Academy,

who

who ſaid, that the Anatomiſts, and even the Philoſophers, reſemble our Hackney-coachmen, who traverſe backwards and forwards, and call all the Streets of *Paris* by their reſpective Names, but never enter into the Houſes. This Sarcaſm is exactly true, when you ſpeak of a Philoſopher, who thinks that his Knowledge ends where his Senſes have no longer any thing to teach him. But let us leave ſuch an abject Method to vulgar Souls. Is it not the Province of Reaſon, when our Senſes fail us, to ſupply and unfold the reſt? Nay, was it not in order to oblige it to walk without a Guide, that Senſes were given to it, in a Degree much leſs perfect, than to a great many Animals? A Bird diſcovers upon the Earth Seeds that are imperceptible to our Eyes. What is it that can be compared, in Point of Sharpneſs, to the ſmelling of the Dog and the Birds of prey? Do not the two Cornets, that ſtand up an End over the Head of the Cat, render his Hearing ſenſible of the ſmalleſt Mouſe? Why then ſhould we raiſe the Dignity of Man on Account of his Senſes, in which he is inferior to the Animals, inſtead of deriving his Glory from the purely intellectual Philoſophy, in point of which he is ſuperior to all? This is the Cant which People are never tired with repeating.

Men may reverence the purely intellectual Philoſophy as much as they pleaſe. But as we are here making the Elogium of Man, we think it our Duty, to draw the Matter of it from real Advantages, rather than from fine Dreams, and Syſtems independent of the Senſes. We take Man as he is, and we find that the real Progreſſes of his Reaſon are owing to the right Uſe it makes of its Senſes. I own that you will find among Animals a few Senſations of a Sharpneſs ſuperior to what we experience. But the Animals hardly excel us in more than one Point, which is their peculiar Share of Perfection. An exquiſite Smell is the Property of the Terrier, who creeps thro' dark Places, and under Briars and Brambles; and a ſharp piercing Sight the Property of the Grey-hound, who uſes it upon the Plain. Whereas Man may, by the re-union of his Senſes, be informed of what concerns him all over the Earth, and of what God has done for him in paſt Ages.

Place a Horſe between two Parcels of Hay, or of Oats, which our Eyes and Smelling may perhaps judge to be of equal Goodneſs, and he never will miſs the beſt, but will conſtantly reject that which is old or impaired. The Delicacy of this Diſcernment relates to his peculiar Intereſt. But it is the Sum total of his Knowledge: He knows neither on what Plain theſe Oats grew, nor what Meadow will yield the beſt Hay. He is beſides perfectly inſenſible of what has no Relation to his Condition or Way of Living. He takes no Delight in the Smell of exquiſite Meats, nor in the Sight of Gold, nor in the *Arabian* Perfumes: Whereas Man tries and gives a Name to every Thing. He oftentimes diſtinguiſhes, with the ſlighteſt Glance, the Productions of one Province from thoſe of another: And you will find in the Collections of Sir *Hans Sloane* and Mr. *Bonnier de la Moſſon*, Samples of the Preſents which Man receives from one Pole to the other. After his Senſes have informed him of the outward Properties and real Qualities of theſe ſeveral Productions, he reaſons upon the Uſe that may be made of them: He compares them with ſome others, or improves the one with the other. He fixes the Uſe of them, and by that Means the Effects, he obſerves, are ſo many Guides to him toward diſcovering ſome new ones. Thus it is that his Senſes and Reaſon, his Phyſics and his Poſſeſſions were made to proceed always Hand in Hand. Thoſe, who ſeparate them, talk ſometimes very loud: But they are no longer in the Order eſtabliſhed by the Creator: They promiſe to one Age Diſcoveries that are the Ridicule of the next. Their Reaſon evaporates, and their Poſſeſſions ſlip out of their Hands. *Leibnitz*, centred in his own Ideas, brings forth Monades, and the pre-eſtabliſhed Harmony. *Van Helmont* promiſes to all the World the Tranſmutation of Metals, and the univerſal Remedy, whereof he has framed an Ideal Syſtem to himſelf, and then dies without having effected any thing, and leaves his Family in a moſt deplorable Condition. *Deſcartes* ſaw in his Reaſon Gold and Iron proceeding from the ſame Maſs of homogeneous Matter: Whereas *Boerhaave* has ſeen, in a thouſand Experiments, that what is no Gold ſhall never become Gold, and that what is Mercury ſhall never ceaſe to be ſuch.

Altho'

Altho' Man is already much indebted to his Senses, for whatever he can know with any Exactness of the Œconomy of the Heavens, of the Outside, and of the very Bowels of the Earth: Here is a new Set of Favours, which he receives from the same Hand, and which are equal or even superior to the other Is he not solely indebted to his Senses for the Knowledge of all that has passed on the Earth ever since its being inhabited, and for all the agreeable Instructions of History, which are so well adapted to give him Prudence, and improve his Heart? His Reason may turn to its own Advantage the several Monuments offered it by its Senses: whereas it finds within itself neither the Dates, nor the Events, nor the Motives of them.

Again, God employs the Ministry of the Senses of Man, when he is pleased to grant him a Treasure far more precious than the bare Knowledge of Facts; I mean the Gift of Faith and Obedience to the Gospel. Reason by itself can no more guess the Choice of the Means by which God has been pleased to save Man, than it can, by its most profound Meditations, guess at past Events, or at what is at the Centre of the Earth. But God did not suffer it to be ignorant or even uncertain of what was sufficient for it. The Monuments and sensible Testimonies of what we are to believe or do are ever standing. How perplexed Reason will be, if it must suggest to itself the Rule of Faith and Morality! But how easy it will be, on the other Hand, if that Rule is already made, if it passes from one Generation to another, and Man needs only have Ears to hear it*.

The Senses and Organs of Man are so exquisitely matched, that by their Help, Reason keeps a Correspondence with the whole Universe; past Things become present to it; and it may exert its Prudence and Industry, upon all God has placed on its Abode. What it is its utmost Concern to know, as well as what it knows is enough to regulate it, is what it learns from the Senses. It meets with nothing but Misery and Uncertainty, whenever it centers within itself. It is conscious of its being itself nothing but Darkness. It is sensible, that far from being entitled

* *Fides ex auditu.*

to despise the Testimony of its Senses, its Appointment is to make Use of them, and that they are the Means granted it to arrive at some Kind of real Knowledge. It shall not then frame a Set of Physics, or an History, or a Religion to itself: But it will receive them from some other Place. 'Tis true, Reason observes and judges; it operates and governs: But that is always on Condition that the Senses shall never cease to be the Monitors and Ministers of its Government They may be the Subject of the Complaints of a Philosopher that wants to draw Man out of his Sphere. But a judicious Mind, who knows the Privileges and Limits of human Reason, will confess with Humility, and yet with Gratitude, that the Senses of Man, though limited in their Relations, are the first Supports of his Power, and the very Instruments of his Salvation.

The POWER of MAN;

Proved from his Pleasures.

DIALOGUE V.

WE have just seen how Man does, by the Concurrence of his Reason and Senses, bear a truly universal Sway, which is the Image of that of God. But can we say the same of his Pleasures? Let us take a View of them; and we shall find that they also are connected with the whole Universe. This may be made good with Regard to the most insignificant and trifling Things.

The Play-thing, that hangs about an Infant's Waste *, is composed of a Piece of Crystal that was cut off the steepest Rocks of the *Alps* or *Madagascar* †, and of Silver Bells, the Matter whereof comes from *Germany* or *Peru*. The Parrot, which is placed near that child to talk to it, was

* That Play-thing, which is a Piece of Coral among the *English*, is a smooth and bright Piece of Rock-Crystal in *France*.

† One of the largest Islands in the World, that lies East of *Africa*.

ſent him from St. *Domingo* or *Zanguebar* : And the Feather, which adorns his Cap, was pulled from the Wing of one of the Oſtridges that traverſe the Deſarts of *Negro-land*, or *Zaara**.

Let us conſider even the ſlighteſt of our Repaſts. How many Provinces vie with each other, and contend for the Honour of ſupplying us with a glaſs of Wine? Do we prefer a Diſh of warm Liquor? *Canada* preſents us with its Capillaires, the *Caraccas* offer us their Cocoa-Nuts and Vanilla, *China* and *Japan* their Tea, and *Arabia* its Coffee. The Bitterneſs of theſe Leaves and Grains ſhall be immediately corrected by the pleaſant Salt of the Canes that grow at *Martinico* or *Cayenne*. The Cup that holds this Liquor comes to us from *Meaco* † or *Nanquin* §, from *Saxony* or *Chantilly*. Thus three Continents continue to ſupply Man even with this meaneſt of his Wants, which yet he may enjoy, and keep ſtill within the Bounds of the ſtricteſt Sobriety.

I ſhorten the immenſe Liſt of his Wants and Pleaſures, by ſaying, that if he is willing to take a View of them in the Heavens, and upon the Earth, he may diſtinguiſh all the Points of the Globe by as many peculiar Contributions. This is one of the moſt pleaſing Methods of framing a Geography to one's ſelf, and an Employment well worthy of him for whom the Earth was created.

But becauſe Man is able to procure to himſelf innumerable Bleſſings, does it from thence follow he muſt be the Image of God on the Earth? Is not the Multitude of his Pleaſures, on the contrary, rather a Diſhonour than a Glory to him? It is that very Rapaciouſneſs, in aſſuming every thing to himſelf, that really betrays the Uſurper and the Tyrant. The Deiſts aſſume an Air of Moderation when they thus cenſure our Pleaſures; and yet it has been obſerved, that they have no Contempt for them, and that their Morals are none of the ſtricteſt: But then indeed there is no Philoſophy that is leſs conſequential and rational than theirs. They look upon Man as an animal that has no Superiority over the reſt, and yet there is nothing which

* The very heart of *Africa*.
† A great City of *Japan*.
§ A great City of *China*.

we do not see these Men dispose of without Scruple. They look with an Eye of Pity on the Dominion ascribed to us in Scripture, and at the same Time dispense with all the wise Rules that set Bounds to that Dominion. Will they become wiser by turning *Anachorets?* But it would be the highest Degree of Extravagance in them to deprive themselves of every Thing here below, and have no Hopes left any where else. Sure the Deist knows neither what he is, nor what he condemns, nor what he approves of, because that Reason, which he takes for his Mistress, was appointed to listen, not to be listened to. Let us then entertain that Notion of our Pleasures which Nature, Experience, and revealed Religion gives us of them.

Pleasures cannot disgrace Man, as they are the Work of God; nor do they render him criminal, since they are a Gift of the Creator. The Power exerted by the Governor of a Province may afford him an Opportunity of doing a great deal of Mischief, and of committing many great Excesses. But it is not his Authority that covers him with Shame; he is only disgraced by the Abuse of his Power. The Pleasures of Man, likewise, are, in the Order of God, so many Proofs of the Excellence of his Condition. They never dishonour him but when he uses them to Excess, and overlooks the Intentions of him who created those Pleasures, and who perpetuates the Distribution of them.

That Wisdom, which created all Things, is the same that came to reform the Disorders of our World. The only Thing it took to task was the Will of Man. All else was good; nor did our Saviour prohibit the Use of them. 'Tis true, he every where presents us with powerful Motives for introducing Purity, Reserve, Dignity, and Rule into our Actions; but above all, he insists upon these Things with regard to the Use of Pleasures. He represented them to us as being the Objects of a lively Gratitude, or as being, on a great many Occasions, the Matter of an excellent Sacrifice, and sometimes of a necessary Privation. But he neither condemned them as bad, nor suppressed them although they were dangerous. He deprived us only of what was contrary to the primitive Institution, or of what a personal Disposition might render pernicious to us. Let any Man name, if he can, one single Pleasure he has refused us.

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He invites us to admire the Beauty of the Robe wherewith God has clothed the Flowers of the Fields. He will have us consider the bright Colours with which God decks the very Grass of our Meadows. I know that this Invitation aims at more than barely making us admire the Flowers and Ornaments our Abode is adorn'd with. When he desires us to take Notice of the fond Care with which God vouchsafes to imbellish transitory Creatures, destined only to supply our daily Wants, he thereby makes us sensible how dear we ourselves are to the Providence of the Creator. But this is not debarring, but rather permitting and ennobling our Pleasures: It is teaching us at one Time a twofold Use of all Pleasures, which ought always to instruct as well as entertain us. Far from blaming that Cleanliness that makes us wash our Face, and perfume our Hair, he will not have that Practice interrupted even on the Day of a voluntary Fast, lest the suppressing of a requisite Decorum, which every one expects to see us observe, should become the Publication of the Good which we were not bound to do. He honoured Marriage by assisting at a Wedding-feast, and, out of Compassion for the Smallness of the Provisions of those that gave it, he changed their Water into Wine; an express Creation, which, far from prohibiting Wine, authorises the seasonable and innocent Mirth resulting from the excellent Quality of that Liquor. Nay, he even honoured with his Praises the Profusion of an exquisite Presume, because an excellent Motive was the Principle of it. You see him ever intent, not indeed on prescribing such or such an Abstinence to us; but on recalling Man to what is the Life of Religion, *viz.* the Love of God, and of one's Neighbour, which only inclines us to honour the one, and be helpful to the other. He lived in the common Way, and never insisted, like other Lawgivers, on meer Forms of doing this or that; which Forms may indeed very usefully prevent or punish our Faults, but may, at the same Time, subsist with the strongest Passions. He strikes at the Passions themselves, because the reforming of our Will necessarily regulates the proper Enjoyment of those Blessings, it had before made an ill Use of. The Disciples of our Saviour, moved by his Divine Spirit, have taught us, that whatever came out of the Hands of the Creator deserves and commands our Gratitude. Their Doctrine, as well

as his, concerning Pleaſures, teaches us to deprive ourſelves of them, in order to be more free and leſs diverted from the Service of God, or to govern the Uſe of them merely according to Charity, or the prudent Management of the Church, to whom it belongs to rule her Children *.

If we even examine the primordial Deſtination of all Pleaſures, we ſhall find in it the Characteriſtics of an immenſe Goodneſs and a ſovereign Prudence. The tender Regard of God towards Man, ſhines moſt conſpicuouſly both in the Quality and the Number of the Pleaſures he has imparted to him. He has made their Attractives inherent to whatever is moſt neceſſary, and multiplied their Number with a kind of Prodigality. What a Splendor in thoſe Torches which gives us Light! What a Loftineſs in the azure Arch that covers us! What a Variety of Colours and Sounds, of Smells and Savours, of Symmetry and Delights of all Kinds throughout our Habitation!

The greateſt Kings leave their Pleaſure-gardens to enjoy the Sight of a fine Field, in common with their Subjects. There is nothing ſo grand or ſo affecting as ſimple Nature. The King, 'tis true, ſleeps beneath a gilded Roof, whilſt the Shepherd takes his Reſt under a Cottage: But beautiful Nature ſtill puts them upon a Level. Both are enlightened by the ſame Sun; both enjoy the ſame Elements, and live under the ſame Heavens. They truly inhabit one and the ſame Palace.

The Prudence of the ſupreme Being is no leſs conſpicuous than his Goodneſs, in the Pleaſures he grants us. He was not contented with intereſting us in the Uſe and Adminiſtration of all the Bleſſings he preſents to us, by cauſing a Pleaſure to reſult from them by the Gratification of ſome one or other of our Senſes; but his Intention was alſo, that this Pleaſure ſhould be quick, and even attractive, or the Abſence of it attended with Sadneſs, and ſometimes with Pain, to the End that it might be a Warning as well as a Comfort to Man; and not only keep him awake, as to what he is to do for his own Preſervation, but alſo be a perpetual Monitor to invite him to do it. There is a Multitude of urgent Neceſſities which Reaſon would not have provided for, had it not been for this Deſign of the Crea-

* Acts xv. and 1 Cor. iii.

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tor. Reaſon would have been but faintly inclined to ſatisfy them, or might even have abſtained from them out of Forgetfulneſs, or on Purpoſe. Hunger and Thirſt, and all our Senſations which provoke, as well as all the Pleaſures which attract and invite us, make up for the Miſtakes as well as the Abſences of our Reaſon, and by Means both efficacious and preſſing, keep Man from being acceſſory to his own Deſtruction.

Pleaſures are not the End of Man.

But let the Motives of acting, which Man finds in his Pleaſures, be ever ſo uſeful and ſtrong; yet they are neither his End nor his Rule. The Pleaſures of Man are not his End, ſince they all of them conduce to ſome further Aim. Appetite inclines us to eating. We eat in order to live, and live in order to work, and the whole is ſtill directed by Religion towards that common End which every Thing ought to lead to. The mutual Attraction of the two Sexes for each other has Marriage for its Aim, and the End of Marriage is the Birth and Education of Subjects, that may perpetuate both the Church and the State.

But if Man was created for no other End but the Promotion of his own Happineſs, the Society is deprived in almoſt every Caſe of what it had a Right to expect. Man thinks he is of Service to Mankind in his Expences, by referring every thing to his own Satisfaction: But while he cauſes the Miniſters of his Paſſions to ſwim in Riches, the vaſt Inequality of the Diviſion of his Favours muſt needs bring Miſery upon thoſe who are at a further Diſtance from him. Piety has ſounder and more uſeful Views; all her Steps lead to the common Good. Her very Moderation and Abſtemiouſneſs, far from being hurtful to others by the ſuppreſſing of certain Expences, do but enable her the better to ſpread new Favours among the reſt of Mankind, and make them flow where an Expence made at Random could never have conveyed any.

As Pleaſures are by no Means the End of human Actions, much leſs ought they to be the Rule of them. Nay, they muſt be even pernicious and deſtructive of all Rule, when they conduce to nothing: For they have been ſubjected to a Rule, merely to obtain that End for which they were

created. Do but change that Order in the leaſt, and you pervert every thing.

A Man is guilty in eating, when he has no longer any Claim to Life, and what Right has he to live, when he refuſes to work? Invading the Property of others is alſo ſubverting every Rule: And what Property is dearer to a Man than his Wife? It is likewiſe an Inſult on Society and Common Senſe, to fill the World with profligate and wretched Creatures, deſtitute of Protection and Education: He then corrupts all Pleaſures, and deſtroys the End of them, who is an Adulterer, or a Fornicator. Whatever is on the Earth has been given up to Man; but whatever is within Man was ſubjected to Reaſon and Rule. We ſhall ſee, in its proper Time, that this Reaſon, as well as the Conſcience which attends it, has not been abandoned to the Chance of its own Deciſions, or the Rule of its own Fancy. It is not its own Guide and Light. It was originally governed by Precepts given to the firſt Men; and ever ſince the Manifeſtation of our Saviour, it finds its Rule and a perfect Security in the Simplicity of Faith, and an Obedience to the preaching of the Goſpel.

MAN conſider'd as GOVERNOR.

The Aſſiſtance he receives from the Animal Functions.

DIALOGUE VI.

THE Organs of the Body of Man viſibly ſubmit all the Earth to his Reſearches and Induſtry: And as they likewiſe readily obey all the Dictates of his Will; that Will, of courſe, rules over all the Earth, and ſubjects it to itſelf.

It is a Thing which appears at firſt very aſtoniſhing, that our Will, which diſpoſes at its Pleaſure of all terreſtrial

ſtrial Bodies, is no longer Miſtreſs of any thing, when the Action of the Veſſels which conſtitute the inward Parts of our own Body is to be regulated. The Lungs, the Heart, the Stomach, and the Brain itſelf, will not wait for Man's Commands in many Things. They have an Action of their own, independent from, and even ſometimes contrary to all his Deſires. He may, indeed, by many tried Precautions, and by Arguments grounded upon Experience, prudently attempt to reſtore or maintain a good Oeconomy in his inward Organs. This is granted to the Diſcernment of an excellent Phyſician. But Man knows not the Organs of his Brain: How then can he know the Action of them? Even the Manner of his Digeſtion is a Secret to him; and we find here, as well as in many other Caſes, that a very ſmall Portion of Light, if any, has been granted to us, wherever we had nothing to govern. I am not ignorant with what an Aſſurance a Philoſopher will come and tell us, that Digeſtion is no more than the Action of a triturating Muſcle. Another, who laughs at the very Name of Trituration, will tell you, that Digeſtion is brought about by a ſaponaceous Water. Others will alledge other Diſſolvents. But, let us put into the Hands of thoſe Philoſophers Liquors, Herbs, Vegetables, Bread, and Meats of all Kinds: Let us allow them Mortars, Peſtles, Water, Soap, Fire, Salt, Vitriol, Spirit of Nitre, and as many Diſſolvents and Agents as they pleaſe: Let us add to theſe Apparatus's, Sieves and Strainers, in ſhort, all the neceſſary Tools for grinding, diſſolving, and filtrating: I ſay, that notwithſtanding all thoſe Things, they never will be able to give us one ſingle Drop of Chyle, and ſtill leſs able to ſhew us the leaſt Drop of Blood. They may eaſily counterfeit the Whiteneſs of Milk, by diluting the Flower of a few Almonds with Water, and calling that Almond Milk; but there is an immenſe Diſtance between that and real Chyle, between that and real Milk, or right Blood.

I will ſuppoſe that Man may poſſibly arrive at diſcerning in a Manner leſs confuſed the Action of his Intrails; yet will it be conſtantly true, that his immediate Government is no way acceſſory to that Operation. He governs the Choice of the Meats, and the Trituration which is made of them under his Teeth. But the Bread ground by

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the latter has hardly got to the Orifice of the Œſophagus, but it is entirely out of the Power of Man. The Stomach, into which this Food deſcends, is a perfect Abyſs to it. Man is ignorant whether it ſhall be digeſted there well, or not, and the whole Work of his Inteſtines is altogether inacceſſible to his Inſpection. It is performed without him from Beginning to End, and commonly in his Abſence, ſince he never digeſts better than when he is aſleep.

Shall we deem this an Imperfection in Man? It is rather an honourable Diſcharge, and a convenient Exemption. He has thereby been excuſed the Cares of Digeſtion, and the innumerable Particulars of ſo many inward Operations that would have oppreſſed him, as they muſt have waited for his Commands and Direction. But, what could be the Aim of this Exemption, if not to enable him perpetually to act externally, and to give himſelf up to the Exerciſe of his Talents?

What we are allowed to perceive of the inward Œconomy of the human Body is ſtill more miraculous than any thing we have hitherto ſeen. But let us frankly own the Truth: Whenever we hear People ſpeak of Stomach and Inteſtines, of Gall and Coction, of Chyle, Humours, and Secretions; our Imagination is ſhocked, and the Organs themſelves, as well as the Matters that circulate thro' and are contained in them, are ſo many Objects we naturally turn our Eyes from. The Sight of them appears hideous to us, and makes us ſhudder, unleſs Reſolution, and the Habit of buſying ourſelves profeſſedly about them, have, by little and little, taken off our Diſguſt for them.

We know of a certain Syſtem of Metaphyſics, that would fain expoſtulate with the Author of our Being, for having endowed the ſeveral Parts of our Abode with ſo many powerful Attractives, and, at the ſame Time, inſpired Man with an almoſt invincible Averſion for the Sight of the inward Veſſels of the human Body; although we were ſo much concerned in the Structure and Action of them, and that Action could never be too well regulated, as they make a Part of our Being.

What raiſes here the murmuring of a vain Philoſophy, is in good Truth a Diſpenſation full of Wiſdom, and a Precaution infinitely uſeful to Man. What God entruſted to our Induſtry and Management, has ſeldom any thing diſguſt-

disgustful in it, and the Incitements to it render the Work agreeable to us. Agriculture, Commerce, Fishing, Hunting, and the Arts in general, have a Thousand Charms for Man, that encourage his Efforts, and make him overlook the very Toils they are attended with: Whereas, an unconquerable Aversion diverts his Eyes and Thoughts from whatever recalls him to the Functions of his Intrails, and the whole inward Frame of his Body. Now could any thing be better contrived, since this Operation is so totally independent on the Direction and Knowledge of Man? His Happiness does indeed consist in being strongly inclined to what he can do with Success, and powerfully diverted from what he can neither govern nor conceive.

There is then in Man a Kind of Ignorance and Incapacity, which, far from arguing any Disorder or Misery, facilitates to him the Enjoyment of his Privileges. What God reserves to his own divine Operation, without requiring any thing of Man towards it, aims at sparing him so much Trouble: And that Exemption, which increases his Liberty, is a true Motive of Gratitude. It renders us but the more sensible that God leads us one Way, and Philosophy another. When his Reason has attempted to shake off the Yoke of his Senses, and find every Thing in itself, it neither finds nor procures any Thing for us; but, when it follows Experience, and the Certainty of its Senses, Step by Step, from that Moment it is in the Order that confines it to a limited Compass of Knowledge, and its Toils are encouraged by a Series of new Acquisitions and good Success.

MAN consider'd as GOVERNOR;

Demonstrated from the Faculties of his Mind.

The Activity of MAN.

DIALOGUE VII.

THAT Man was destined to apply to his own Use, and govern whatever is upon the Earth, is a Matter of Fact no longer to be doubted, as his Strength and Dexterity, his Wants and Pleasures, and the Advices and Operations of his Organs, generally exert themselves upon, and extend to every Thing in the Globe. But we know hitherto no more than the external Part of his Government. We have not as yet carried our Inspection any farther than to the Ministers appointed to inform him, to give him Intelligence, or execute his Orders. Let us now view the Governor himself, even the human Understanding; and be satisfied with what it is possible and necessary for us to know of it.

Every Thing on Earth is administered and governed by the Body of Man. But the latter moves and acts under the Command of its Mind, which thus becomes the Moderator of the whole. A King is never truly such, or is only so by Name, unless he has both Power and Strength to make himself obeyed; Understanding and Counsel to judge of all the Things he is to set in Order; and the free Choice of those Means which are most conducive to it. The human Mind ought then to have, towards exerting its Authority, a powerful Activity that submits to it the Things within its Province, a sufficient Share of Intelligence to know the Objects of its Operations; in short, the free Choice of the Means that are most suitable to make

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an Advantage of every Thing. Now we can demonſtrate, that all theſe Qualifications are to be found in Man, and in Man alone; you muſt be throughly convinced that he is the Image of God on Earth, and appointed to improve every Thing there, by a rational and equitable Uſe: For, if God is the Lord of all Things, he is ſo through his Omnipotence that created all; through his Omniſcience that makes him know all, and through his ſupreme Freedom that chuſes what is good, and moſt ſuitable to his Purpoſes.

The Activity of Man.

That powerful Activity of Man, the firſt Foundation of his Glory and Reſemblance with God, is already known to us from the bare Inſpection of his Organs; and of the Works wherewith he imbelliſhes the Earth. It would be very agreeable and natural enough, here to conſider in a particular Manner, the magnificent Detail of them: But it being improper to repeat the ſame Things over and over, we ſhall poſtpone this Enumeration, till that Time when we are to conſider him in Society, and take a View of his ſeveral Works. It ſuffices for the preſent to obſerve in general, that the greateſt Honour to which God has called Man upon the Earth, conſiſts in being Inventor and ſupreme Orderer there. He is viſibly Inventor on the Earth, as he fills it with Works of all Kinds, which God never placed there; and is alſo the general Diſpoſer of all; ſince he buſies himſelf ſometimes with the regulating of his own Conduct, ſometimes with the reforming of that of others, and ſometimes with the Management of a Multitude of Enterprizes, partly executed under his immediate Inſpection, partly at a Diſtance from him, and partly at the four Quarters of the World.

Caſtors build Huts, Foxes dig Holes, and Birds make Neſts to themſelves. No more muſt be required of them. An invincible and uniform Impreſſion conſtantly brings them to that Point, and, without Reaſoning, ſtill inclines them to produce Works which never vary. If they did reaſon, their Works would be as various as their rational Operations. But Man, when he received the Impreſſion of an Activity, that makes him hate Inaction, was not confined to one ſingle Method or Manner of employing himſelf. He was given over to his own Reaſoning and Counſel.

Counsel. He searches; he tries; he deliberates; he combines: He makes new Observations, new Projects, and new Works. We see coming out of his Head and Hands Things of which there was no Model in Nature; a Mill, a Gun, a Watch. He not only imitates God, in introducing here below Productions which never appeared there; but he, like God, never ceases to be active; he, like him, preserves and renews his first Works, and, as well as him, reforms Irregularities, and re-establishes Rule wherever it begins to flag.

We neither can nor will say, that Man exerts Omnipotence as well as God. That would be a blasphemous Assertion. Man is not a Creator. He can do no more than combine Things already made. But were there in any of our Languages a Word that will clearly express the Faculty which Man has of producing Novelties of all Kinds upon the Earth, and of maintaining the good Things he has already procured for it, that World would express the Power of Man, and be an Epitome of his Glory; as it would describe that Perfection of what brings him nearest to the Creator.

Working.

Working is the Term we are looking out for. Man works upon whatever the Earth contains; he is therefore the Image of the Creator. Labour is only the Exertion of that fruitful Activity, whereby he conceives a Series of useful Thoughts, or produces, entertains, and finishes a Multitude of outward Works. Working is then the first Foundation of the true Grandeur of Man, as Omnipotence is the Principle of the Works and Glory of God.

The Works of Man, 'tis true, are indeed attended with Difficulties, Obstacles, and much Trouble. His Labour is hard and toilsome; and this cannot be applied to God. Man, for certain, is very far from being his Image in that Respect. But, altho' Fatigues and Hardships are the just Punishment, as well as the wholesome Exercise of Man, considered as a Sinner; altho' Labour is become so far Indispensable, as he has been condemned to it; yet Working ceases not, for all that, to be still what it was in its first Original. It is the Vocation of Man. Birds are made to fly, and Man was created to work. As the Works of God, both in their Creation and Perpetuity, are the uninterrupted

interrupted Exertion of his Omnipotence; Operating is the perpetual Exercise of the Power of Man. He imitates the Creator, in Proportion as he cultivates the Earth, and assists her in her Productions. This was the Appointment of *Adam*, even in his State of Innocence*; whereas, the more faintly he works, or abstains from Labour, the more he destroys in himself the Image of him who created the World, and who never ceases to re-produce, or preserve there, what he brought to Light from the very Beginning. Such is the Condition of a rational Being. Nothing is greater on Earth than Man, so long as he embellishes it with some new Work. The Moment he desists from that, he becomes no more than a Statue, and loads the Earth with an useless Burthen.

* *Ut operaretur*, Genes. ii. 15.

MAN consider'd as GOVERNOR;

From the Understanding.

DIALOGUE VIII.

THE Sovereign Power of the Creator was never separated from his supreme Wisdom, which co-existed with him before the Universe. It delighted him in the Creation, through the Variety of the Plans of those Works which it offered to his Choice; and ever since the Creation, its Pleasure hath been to dwell among the Children of Men, to regulate their Conduct, and the Operations of their Hands. Thus Wisdom instructed *Adam*, *Noah*, *Abraham*, and him who, of all Kings, had the greatest Share in its Favours, so long as the Seduction of Riches, and the Illusion of Pleasures did not restrain him from listening to its Dictates. It is that Wisdom, which has from Age to Age

Prov. viii 22, *& seq.*

raised useful Genius's, and industrious Workmen. But as God, when he imparted his Power to Man, did not give him his Omnipotence, so when he gave him to partake of his Wisdom, and granted him a vast Capacity of Knowledge and Invention, he did not make that Knowledge as boundless as his own.

He raised him to the Glory of Governing, and ordering whatever was placed in his earthly Abode, that he might exert both the Sagacity of his Mind, and the Dexterity of his Hands. But Man governs and ranges Things already made. He may observe the Number, Dimensions, Action, Merit, and Properties of them: He may, by new Combinations and Changes of Order, put Minds and Bodies in Motion: He may, as it were, create anew: But the Nature and Exellence of whatever he employs were preexistent. It is an easy Matter for him to destroy his own Work. He may break to Pieces the Vessel, or the Pendulum-clock that came out of his Hands; but he will never be able to make those Pieces return to their former Nothingness. The Clay and Copper remain immortal. He can neither destroy nor create the primitive Beings; and God, who has limited the Power of Man, has of Course set the same Bounds to his Knowledge.

There are then, if you will allow me the Expression, two Sorts of Productions; that of God, who has made the Spirits and Bodies; and that of Man, who cultivates, fashions, imbellishes, and applies them to several Uses, by ingenius Inventions. The Objects of the first Creation are made, and it is because Man was not commissioned to make them, that God had rendered them inconceivable to him. But the many Uses to which Man can apply created Things, are the true Object of the human Science and productive Faculty. Such is then the Measure of the Operations of Man, and such the Measure of his Knowledge. If it is glorious to him to enjoy Prerogatives, so great as these are, he, on the other Hand, commits an Error that renders him ridiculous, when he falls to Reasoning, creating Difficulties and Objections, and building Systems upon Objects which are beyond both his Power and his Knowledge. *Bayle* became a speculative *Manichean*. *Locke* was inclined to become a Materialist; *Newton* had some Dispositions towards being an *Arrian*, and a great many Metaphysicians

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now-a-days become Deiſts, by arguing at random upon the Nature of Spirits and Bodies, and of God himſelf, and the very Order of his Decrees. They all of them will juſtify the Boldneſs or Singularity of their Opinions, by ſaying they have followed pure Reaſon, rather than the old Prejudices that have been circulating among Men, from one Age to another. But they have, every one of them, ſuppoſed in Man a Prerogative which he enjoys not, even that of obtaining from his Reaſon clear and unqueſtionable Anſwers, upon all the Queſtions he is pleaſed to put to it. That was not his Vocation, nor his Kind of Intelligence. The moſt Part of them, on the contrary, have neglected to uſe a moſt real and moſt honourable Privilege, which Reaſon actually enjoys, of regulating and improving his Dominion, by the good Advices of Experience, and by outward Teſtimonies, which ſufficiently inſtruct him in the Order of Nature, and Revelation. It has been a general Miſtake among them, to expect Light from Reaſon, that was appointed to receive it. They thought it capable of underſtanding, by Dint of Arguments, what God has reſerved to his own proper Operation and Knowledge. It is no Wonder, indeed, that they have erred and gone aſtray ſo variouſly, and that Darkneſs ſhould have increaſed more and more as they went on: They had leaped beyond their Sphere.

Ever ſince Men have been on the Earth, uninterrupted Experience has taught them, that their Knowledge had a Relation to their Activity: That they have Underſtanding enough for the Things they can do; but that they are vaſtly limited in the Knowledge of what exiſts or acts independent on them; for Inſtance, in the Knowledge of the Structure and Action of the Organs of their own Body, or in that of the Operations of their intellectual Faculties. All which is executed without their knowing the Manner of it.

This Obſervation is the Solution of a Queſtion which has very much puzzled the moſt contemplative Philoſophers. What is, they will aſk, the Manner in which Man ſees Truth? How is his Knowledge formed? Is his Underſtanding a Looking-glaſs, in which Truths come and paint themſelves? Or how is it conceivable, that an Underſtanding can be a Looking-glaſs? Does he ſee

Truths in God, in whose Substance they are immutable? Does he bring into the World a Stock of common Truths, that constitute what we call Common Sense, and the Basis of our Arguments? Or does our Understanding operate only in a general Manner, and apply to every new Case the particular Things we learn by Means of our Senses? And in this last Case, how and upon what Grounds will our Reason give its Judgment a greater Extent than there is in the constantly particular Informations it receives from its Senses?

I shall answer this Question concerning the Origin of our Knowledge, by another Question on the Origin and Communication of our Activity to the several Members of the Body. How do the animal Spirits, if any there are, suddenly carry their Action from the Brain down to the very Tip of the Toes? How can they operate in a Manner so opposite to what passes in all Kinds of Mechanics?

It is universally acknowledged, that whatever Things are to be weighed, a small Force may put in Motion, or even overcome a great Power: But, in that Case, the small Force traverses a great Space with Rapidity, whilst the great Force moves but slowly within a very short one. The Velocity compensates for the Weight. A fifty Pounds Weight hooked on the Steel-yard or Roman Balance, hardly rises the Space of half an Inch, whilst the Pound Weight, which is at the Extremity of the Beam, traverses a Space of fifty half, or five and twenty entire Inches. The hand of the Waggoner, who endeavours to raise his Axle-tree, that fell by the breaking of one of the Wheels, turns twelve or fifteen Times the Handle of the Jack to raise the Axle-tree but a single Inch. In any other Case, the Power moved traverses in an equal Time, as great a Space as the moving Force: They are made even in every Respect. If you are willing, for Instance, that a Bale of Silk, which is in one of the Scales of a Balance, should rise and become level with a Piece of Iron that descends in the other Scale, your moving Force must be of equal Weight, and traverse the same Space as does the Force moved: There must be, for Instance, the Weight of one Pound on each Side, and the Pound of Silk which comes down, as well as the Pound of Iron that goes up, must traverse equal Spaces. These are our Mechanics. We have no other

other at *Mexico*, in *Turky*, or at *Japan*. But in the Mechanics of the human Body, every Thing is operated quite otherwise.

First; we do not conceive what the Action of a Will upon a Brain can be. On the other Hand, let that Fluid which the Blood administers to the Brain, whereby the latter puts all the Muscles of the Body in Motion, and the exhausting of which is followed by the Weariness of the Limbs, or by their total Incapacity of moving; let that Fluid, I say, be whatever it will, it cannot but be of an amazing Tenuity, and an inconceivable Fineness, since it so very little diminishes the Volume of the Blood it proceeds from. But that subtle Matter has hardly moved the Space of perhaps one single Point, but the long Lever of the Leg has already traversed a Space of three Feet, and transported the whole Weight of the Body to the Distance of half a Fathom, or conveyed the Action of a long Flail the Length of six Feet from the Thrasher. Here the small Force makes a short Motion, whilst the great Force traverses a long Space. The above-mentioned Fluid is no sooner bid to flow, but the Arm has already executed the Order it receives to act at the very same Time: Not the least Delay is allowed that Arm, to compensate the Celerity of the Fluid by the Slowness of the Mass of the Muscle. All goes together, the Will, the Spirits, and the Arm. This is a new Kind of Mechanics, which confounds and absorbs the Mind of the most consummate Master of them.

I doubt not but every Thing is mechanically executed in the Motions of the Body, since all the Actions of it are assisted by Cords and Strings, by Impulsions and Retractions; in short, by a Variety of Instruments of Communication. But this Sort of Mechanics is beyond our Reach: It is of a superior Kind, and God has kept it to himself alone, as well as the Motions of our Bodies, and of the whole Universe, which are executed without our having any other Share in them, but that of willing or observing them.

What we have just said of the moving Principle of our Limbs, and the Means of their Communication, may likewise be said of the Origin and Progress of our Knowledge. Our Activity is indeed a noble Present: But the

Manner of its Beginning and Continuance is incomprehensible to us. Our Understanding is an inestimable Favour: But we cannot conceive what that Principle and Tie is, that causes Men, who never saw one another, and between whom all Manner of Communication is suppressed, to unite in adhering to one and the same Truth, and to a Set of common Ideas. Every Body is fully sensible, that the Study of the Anatomy of the Leg and Brains is not necessary towards Walking or Dancing, even in the highest Degree of Perfection. A Dancing-Master would get but very little Money by such a Study. It is likewise a meer Loss of Time and Trouble, and a Method perhaps infinitely more ridiculous and more dangerous than the foregoing, to attempt the improving of one's Mind by making long Searches after the Origin of our Ideas, and by profoundly meditating upon the Nature of common Sense. The Activity of the Body, and common Sense, are two Instruments we have been provided with by Almighty God. His Gifts are fruitful in great Effects. They need only be made Use of, without attempting in vain to understand the Communication of the muscular Motions, or to perceive distinctly the Source of our Conceptions.

Instead of launching into the undeterminable Dispute concerning the Origin of common Ideas, the clearing of which would require a thorough Knowledge of the Nature of God, of that of our Souls, and of the Manner in which the latter is united both to God and the Body; we must be contented with knowing or feeling that it is so, without conceiving the Manner of it. God has not made the right Use of our Legs to depend upon the Study of the Brain, whence the Nerves that move our Legs proceed. The Brain, which performs these Operations, is an inexplicable Mass. Nor has God made the right Use of our Understanding to depend on the Study of the Nature of Spirits. We distinctly feel the Activity and Operations of it, without knowing what it is. Let us then be contented with observing, that God has framed the Understanding of every individual Man, so as that they all of them might unite in the Knowledge of the same identical Truths; just as he has given the same Form to the Eye of the *Asiatick*, and that of the *European*, and provided them both with Legs fit to carry them from one Place to another by alter-
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native Motions, which they are at Liberty to give themselves whenever they please, without understanding any thing of the Matter.

The pretended Difficulties which *Montagne*, *Charron*, and other *Pyrrhonians*, have affected to heap one upon another, in order to depreciate our Talents, and root out all Sense of Gratitude from our Minds, will never hinder us from perceiving very distinctly the Views of the Creator, in those Favours which he was pleased to bestow on us. We remember to have seen a Man without Arms, who had exercised his Feet in the Art of Spinning: But will such a Singularity as this authorise any Man to say, that our Legs were not made to walk with, and that we only chuse to employ them that Way, rather than use them to spin? Many People look upon the Nose as a convenient Support of the Instrument that strengthens the Eye-Sight: But can we say, nevertheless, that the Nose was not made to judge, by Means of its smelling Faculty, of what the Mouth ought to admit or refuse, and of the Infection of the Air we should avoid breathing in? We may possibly prefer the Pleasure of having a small Foot, and a Stature artfully raised a few Lines, to the Satisfaction of walking in a free and easy Manner: We may be fond of raising our Bodies two Inches from the Ground, by Means of a wooden Peg fixed under our Heel, or run the Risk of laming ourselves, by squeezing the Extremities of our Feet by a violent Force, as is the Practice of the Ladies in some Countries (perhaps in *China*:) But their Contempt for the Advantage of walking, does not keep us from being sensible of its general Destination. We have seen likewise very ingenious Nations, who thought it proper, by express Laws, to permit Fathers and Mothers freely to dispose of such of their Children as they fancied were supernumerary, by killing them immediately after their Birth, by exposing them, or by getting rid of them afterwards by pious Consecrations. 'Tis what the *Grecians*, the *Romans*, and all the *Canaanites*, have formerly thorized, who thought it their Duty, on some Emergencies, to sell, or even make Burnt-offerings of them to *loloch*. But is it less true for all that, that the Love of athers and Mothers for the Good and Preservation of their ildren, makes a Part of common Sense. The Tears

which at those Times trickled from the melting Eyes of the Parents, and the Care which they took to drown with the Noise of Drums the Cries of those tender Victims, were plain Vindications of natural Sense, and betrayed in these covetous Devotees the same Grounds of Humanity that were in the Heart of those who had an Abhorrence for their detestable Practices.

It is a known Matter of Fact, that the *Chinese* will oftentimes bequeath their Fortune to a College of Bonzees, and let their old and sickly Parents die for want of bare Necessaries. These mad Whims, occasioned by Avarice, and the Cheats of Bigottry, may support themselves by the Protection of popular Customs, or human Laws: But they can never take Place any where, without raising a secret Indignation in their Hearts of those who see old Age thus given over to Misery and Desolation: And it will still be true in the remotest eastern Regions, as well as on the Confines of *Europe*, that the Respect of Children for their Parents, and their Obligation of sustaining them in their old Age, are, and make a Part of common Sense.

God then has framed all Men so as that they might perceive the same Sun, the same Objects, and the same Light, by opening their Eyes; and apprehend the same useful Truths, by making Use of their Reason. All the World over, every one is willing to be happy: All the World over we calculate, take Dimensions, love our Fathers and Mothers; and it is a common Notion all over the World, that we ought to do to others as we would be done by. Men of all Countries have a Notion of an Intelligence that rules the Universe, and they pay their Homage to him: They expect a Justice that will reward the Good and punish the Wicked, and have a general Abhorrence for those who affect to swerve from such common and universal Ideas. Education, or a false Philosophy, may possibly occasion some small Alteration or Variety in these Notions. But, notwithstanding these local Particularites, Men are always, in the End, brought back to common Sense, which proves superior to Education and Philosophy, because it springs from a far more excellent Source. There is then a permanent Stock of Ideas in all Men, that supplies them with Truths, Knowledge, and Sentiments of general Usefulness. Whether, then, the supreme

supreme Truth is intimately present to all Minds; or whether it has, with indelible Characters, imprinted the same Principles in every individual Mind; or in short, whether God has regulated and disposed our Faculties, so as to enable us to acquire the same Knowledge by a Likeness of Sensations, and the Conformity of Experience; it is an indisputable Point, that the human Mind, if it will but be attentive, can and will perceive, judge, reason, and arrive at the very same Principles of Sciences and Conduct all over the Earth.

When God gave Man the Faculty of discerning Truth, without understanding any thing in his own Being and Activity, he visibly aimed at sparing him needless Distractions, and at inclining him efficaciously to the Exertion of that Faculty. The Anatomy of the Trachea is not what can enable a Musician to sing, and a Man of Experience may never read the Essay on the human Understanding, and yet be able to make wise Motions in the Councils of Kings, to judge according to the exactest Truth in a Court of Judicature, and take the wisest Measures in the Management of his own Affairs; whereas Metaphysics would leave him, with Regard to these Things, in the most profound Darkness, or perhaps only lead him from one Mistake to another.

There is in Man a kind of Ignorance that disgraces him; even that of his Obligations and Duty. It is voluntary, criminal, and even sometimes within the Reach of penal Laws. There is another kind of Ignorance which he ought not to be ashamed of: It consists in the Bounds which God has set to his Understanding, and, as it helps him to confine himself within the Verge of his own Conditions; it is rather a Benefit than a Matter of Complaint.

But, if it is a miserable Error to lament the Weakness of the human Understanding, as if it were the Work of an ill-designing Principle, or of an evil-disposed Deity; it is an Error equally fatal to attribute to that Reason, whose Limits are so easily perceived, the Power of judging of every Thing, and of deciding any Question whatsoever. Our Reason naturally finds within itself the Principles of a judicious Curiosity, together with the Motives of a wise and sober Circumspection. How much the more reserved and submissive will it then be, if God, in order to spare it

the Delays and Doubts which it would experience in the Search after the Truths relating to our Salvation, has all at once fixed its Speculations in this Respect by the publick and easy Rule of the divine Revelation? Sure, if he has vouchsafed to grant such a Supply towards making up for our innate Weakness, (which we may easily convince ourselves of by the Testimonies that warrant the Matter of Fact, and even prevent all our Searches after it) it will be a willful Error to listen to the Discourses of a few *Beaux esprits*, and to pretend to bring the Rule of our Belief and Morals back to the Tribunal of our Reason: As it will, on the contrary, be agreeable to common Sense and good Conduct, to submit our weak Understanding to the Obedience of Faith, and never to exert our Activity and Understanding any otherwise than according to the Bounds within which God has been pleased to confine the Use of them.

The DOMINION of MAN;

Proved from his Imagination.

DIALOGUE. IX.

THE Intention of God, in that Portion of Light which he has imparted to us, is again evidenced by the two Assistants he has placed near the human Understanding; I mean Imagination and Memory.

Imagination.

Half of our Being is Body, and the greatest Part of our Operations are relative to some of the Bodies that surround us. God, who was not willing that we should be tempted to abandon our actual Condition and Relations, and transport ourselves, before the Time, into a State purely intellectual, or into too sublime Contemplations, that would draw us out of our present Situation, has purposely decreed, that all, or almost all, our Thoughts should be attended with, and assisted by some corporeal Image or other. Nay, those of our

our Operations that are merely rational, and our moſt intellectual Ideas, ſuch as arithmetical or algebraical Operations are directed, fix'd and carried on by ſenſible Signs. Were it not for ſuch Help, our Thoughts would either not be conceived at all, or would ſlip out of our Minds. Our uſual Knowledge is either procured, aſſiſted, or occaſioned by our Senſes; and it is for this Reaſon, that our Sciences and Knowledge moſt commonly aſſume the Form of ſome of our Senſations. Hence our Repreſentation of God as a bountiful Father, of whom we are the beloved Family; or as a King full of Majeſty, whoſe Glory reſides and manifeſts itſelf chiefly in the Heavens. We repreſent our own Soul to ourſelves under the ſenſible Notion of a Breath, of a Lamp, or of a light Flame. The Habit we have of thus attributing to Spirits Things which belong only to Bodies, in order to make up for the little Knowledge we have of the Nature of Beings, cauſes us to aſſign as readily ſpiritual Properties to bodily Subſtances, as if the Thoughts which thoſe Bodies raiſe in our Minds by their Action did actually reſide in thoſe Bodies. Thus it is that we ſuppoſe in the Heavens the honourable Function of publiſhing the Glory of God: Thus we aſcribe to the Sun and Moon the Care of governing Nature, and regulating our Days; and ſuppoſe in the Winds an Intention of conveying Deſtruction or Plenty every where*. We ſpeak to Rocks and Deſarts, as if they were endowed with Underſtanding. We invite Rivulets and Birds to join their Murmuring and Notes with our Voice to praiſe the Author of all Good and Beauty, as if they could have any Knowledge of his Bounties, or our Invitations.

This way of thinking ſeems to betray a great Want of Exactneſs. Ought we not to ſhake it off, according to *Locke*'s Wiſhes; would it not be better to utter every Truth in a philoſophical Manner? There would be a vaſt Advantage in defining every thing by its Genus and Difference, and then proceeding methodically to Syllogiſms and Enthymems: That would be cold and inſipid indeed; but the Tireſomeneſs of ſuch a Style would be fully recompenſed by a vaſt Clearneſs; and is not this the only Means of ſtrengthening our Reaſon?

* *Quidve ferant venti, quid cogitet humidus auſter.* Virg. Georg.

The Usefulness of Imagination.

Those who have introduced the Custom of speaking and writing in this Manner, did not sufficiently know the Capacity and Wants of Man. How many young People have we seen discouraged by the scholastical Jargon! A Method that is altogether gloomy and disgustful, can have no other Effect, but to make us abominate all Schools, and shun all scholastick Audiences. There is a Kind of People in the World, who will talk of nothing but extending our Reason, and increasing the Vigour of the human Understanding You would be apt to think, on hearing these great Promises, that they are Genius's of a more sublime Nature than the Generality of Men, and their Understanding much stronger than ours. Their Art consists in confining themselves within a Set of dry Notions, altogether void of sensible Ornaments; in never having recourse to Memory and Erudition; in despising the Eloquence of Images, and the least Assistance of our Imagination; as if sound Reason was inconsistent with good Taste. We shall see, I hope, when we come to what constitutes sound Logic, that the Health and good Constitution of our Understanding can never consist in Abstractions of this Kind Those who fancy that they render it more vigorous and solid by this Means, do but extenuate and infinitely impair it, as they strip it of the Supports God intended it should always rest on: And though their Meditations should lead them to some kind of Truths, they are either perfectly useless, or Thoughts that will only glance upon the Mind without ever entering into them. The three short Chapters that compose the Sermon of our Saviour on the Mount, have done more Good to Society in illustrating a few luminous Maxims, by very lively and affecting Images, than all the Logics in the World, and have conveyed more Light and Exactness among Men than *Locke's* long, tedious, soporating Metaphysics on the human Understanding ever did, or could do. A great many learned Men have, in all Ages, committed the Mistake of separating Things which God had most strictly united in Man, and of attempting to improve one single Faculty of his, by separating it from the others, whose Company is its Help and Perfection.

Our

Our Reaſon, which they promiſed to render able to judge and enquire into every Thing by Help of their Rules, is not more obliged to explain and define, than it was appointed to underſtand every Thing. It may know God, a Spirit, and a Truth, by a cautious Behaviour, from inward Senſe and Experience: *Quærere Deum ſi forte attractent**. But whenever we attempt to ſay what Things themſelves are, there is indeed no Rule, nor any Abſtraction, or Meditation that can or will then aſſiſt us. It is a moſt fruitleſs Attempt to pretend, as Metaphyſicians do, to let Reaſon into the Secret of Beings: God has reſerved that to himſelf. Ordinarily it is enough for us to know them from their Effects, from their Relation to our ſeveral Senſations or Wants, and even from their Reſemblance, in ſome Reſpects, to other Effects already known. It is then no Wonder that Images ſhould be ſo very convenient to us, when we are deſirous to diſcourſe upon them.

Would we ſpeak of God, we may do it according to the moſt ſublime Reaſon, by conſidering him as a Being which is the Principle of all Beings, as the univerſal Cauſe, in which Power, Liberty, and Order reſide. Theſe Notions, although they are very far from making us comprehend what the Nature of God is, yet are infinitely juſt and true. But, as they are abſtruſe, and not eaſily perceptible, they never can affect us ſo much as thoſe of a Father, and a Judge. The latter are very fit to affect the Multitude to a good Purpoſe, and, as well as the former, having nothing in their Meaning but what is of the utmoſt Truth and Solidity. The Neceſſity we are under, at preſent, of living, not indeed with pure intellectual Beings, but among Bodies, and dependent on a Croud of corporeal Ties, renders the Services of Imagination abſolutely neceſſary to our actual Condition. Imagination ſpeaks to us of Things, not conformably to what they are in themſelves; which is but of little Signification to us at preſent; but according to the Concern we ought to have in them. For Inſtance; Is it not of infinitely more Concern to us to love our Father, and dread our Judge, rather than to meditate upon the being *per ſe*, and the being *per accidens?* The purely philoſophical Reaſon, even when it commits no Errors, inſtructs

* Acts xv. 2. 27.

but

but little, as it is but little attended to; and its Advices can never be of Service to us, without the wise Imbellishments of Imagination.

The Dangers attending Imagination.

On the other Hand, and in Consequence of the Remark already made on the Necessity of the Concert of all our Faculties, Imagination, which is so lovely when in Company with, and under the Direction of Reason, would infallibly lead us astray if it was alone, or did pretend to assume to itself the first Rank. There may be something false or excessive in the corporeal Images it presents to us, and its Pictures, when not regulated, will degenerate into Extravagance. Reason and Imagination must then always walk Hand in Hand, and in a constant Correspondence. But in what does that perfect Harmony and Agreement consist? Reason must stedfastly adhere to such Truths as are justified by Experience, and always reserve to itself the Choice of what it ought to present to our Understanding, and those Images which it may think proper to call to its Assistance: Whilst Imagination, lending a modest and ever obsequious Hand to it, makes it its Study to render the Instructions of its Mistress more affecting, without being itself too preceptible.

It is this perfect Subordination of Imagination to Reason, that renders Eloquence energic and prevailing; that gives Poetry its Fire and Pictures; that conveys Variety and Unaffectedness into Conversation, and never fails to render all our Arts and Talents equally pleasing and successful.

MAN consider'd as GOVERNOR;

Proved by his Memory.

DIALOGUE X.

IMagination is not the only Help, wherewith God was pleased to strengthen and adorn our Reason. He added Memory to it, and has, by this new Faculty, still better characterised the Vocation of Man, who is appointed to take Notice of whatever passes upon the Earth, and keep a Register of all, because he presides over all, and is to apply every thing to its seasonable and proper Use.

The Animals are not without some Kind of Memory. Those who are to live independent and provide every Thing for themselves at a Distance, and without requiring any Assistance from us, easily distinguish the Avenues of their respective Haunts, and the Marks of all the Things that concern them. Those who are to remain near Man, and be perpetually at his Command, know his Habitation, Features, and Voice. They accustom themselves to whatever he requires of them, and are ever ready to execute his Orders upon the first Signal. But their Memory is limited within a very small Compass of Functions and reiterated Signs, which are the same over and over. If you take them out of that, you no longer find any Sensibility or Reminiscence in them: But the Memory of Man is in a Manner as extensive as Nature itself. It is a vast Repository, wherein he ranges the Names and Situations of the Stars, and the successive Displacings and critical Returns of the celestial Bodies, at such and such Times and Points. He finds again there the Names, Features, and Professions of several Thousands of his Fellow-citizens exactly titled and registered. He will shew you there, if Occasion requires, not only the Streets of a large City, but all the

Habi-

Habitations in the World, that have been famous by remarkable Events, by desirable Productions, or by a vast Resort of Traders of all Kinds. His Memory keeps for him, in the best Order, the Names, Figures, and Properties of Animals and Plants, and of whatever has a Form, or is of constant Use in Nature. He sees there the Names and Services, of the numberless Instruments that will help his Hand to work the several Riches of his Abode. His Memory is a faithful Journal, wherein he sums up the whole Series of his Life, and runs over a Crowd of Events he has been a Witness to, in order to draw from them proper Models for the Regulation of his Conduct. The amazing Variety of the Objects he collects in his Memory, is so far from occasioning any Confusion there, that his Faculty of recalling to his Mind the Things he sees no more, is always stronger in Proportion as he exercises it oftner. His Memory may, if he pleases, embrace the several Pieces that compose the Life of Mankind in general. It entertains him very agreeably with the Particulars of all Climates, and relates to him the Good and Evil that have been done from Age to Age. If it happens to deceive him, it is seldom for any other Reason, but because he suffers it to be idle. The more he exercises, the more pliant and quick he finds it.

The Monuments of the History of each Nation have Bounds; but the Memory of Man has none. It will join one History to another. What it has once admitted in good Order, (especially when it retains it with the strong Ties of Reasoning and Pleasure) is a Depositum it preserves for us all our Lives.

What I wonder at most of all, is the Perspicuity that is maintain'd among these Images, which no Length of Time, nor any Luxuriancy, can possibly efface or embarrass. Somebody shews me the Picture of a Man, whom I have not seen for Twenty Years together. I immediately find a great many Faults in it. I do not think it altogether unlike the Original: But the Mouth is too wide; the Contour of the Face is too much upon the round; the Eye is too full, and looks sad. Those who have lived with the Man I speak of, find that I judge right of the Picture. Pray, where is the Rule that fixes my Judgment? Where is the Voucher that can authorize my Censure? It is another

ther faithful and indelible Portrait, which the bare Sight of that Man has left in my Memory, and which a Million of other Pictures placed by the Side of it, cannot hinder me from distinguishing directly. Notwithstanding this amazing Multitude of Images, which Man does not always see, but which he keeps in Reserve, to make use of occasionally, he has Table-books besides, wherein he now and then peruses the broken Materials of his numerous Readings, and consults Pieces that are less connected, and more difficult to keep in Store, such as the Terms, Idioms, Phrases, and peculiar Delicacies of three or four different Languages. It is his Memory that supplies him seasonably with the Discoveries of the best Genius's of every Age; with the ravishing Strokes of the greatest Orators and Poets; with the Reflections of Men, whom a long Experience has rendered perfect; in short, with whatever he has been able to learn in Consequence of his own Remarks, or by Means of the Works of others.

When he is arrived at the Knowledge of certain Truths by Reason, and has made himself sure of the Acquisition of them by Experience; he depends upon his Memory for the keeping them. It is answerable for them to him. It lays them before him in proper Time, not with every particular Proof of them, but in a compendious Manner, and by way of Conclusion. One single Maxim, or even a single Word, which it recalls to his Mind seasonably, spares him much Study and needless Repetitions. He finds there, at any Time, the Edict, or the Table of the Law, which is to be the Rule of his Operations and Conduct, in every Instant of his Life.

How is it possible, that one single Head should set in Order this amazing Multitude of Ideas, so very wide from each other, and not the least Trifle be mislayed in that Magazine, provided it is only reviewed now and then? There, as well as every where else, it is the Eye of the Master that keeps every Thing in proper Order.

But he experiences in his Memory, a Kind of Conveniency, never met with in common Magazines. It is a general Custom in the latter, sometimes to displace and remove a great many Things, in order to find what is looked for. You must at least read the Tickets, to know what you are to fix upon: Whereas it is the Reverse in our Memory.

mory. If Man is willing to make Use of what he has seen or tried, that has a Relation to the Object that fills his Mind; this single Intention of his, does the Business at once: For, instead of being then obliged to run over and peruse the Table-books, in order to find his Ideas there, it is the Ideas themselves that come and offer to him of their own accord. The others, at the same Time, keep at a Distance. That which immediately concerns him, after it has ministred to him, disappears in its Turn, though still ready to shew itself again, upon every new Command. What can be the Corner of the Brain that serves them for a Retreat? Nay, what Relation is there between Ideas and a Brain? What Vessels, or what Streams of Spirits, can possibly assist these Ebbings and Flowings of Thought? What is it can awake them from a long Sleep, and immediately lull them into it again? What can animate all those Services with so much Variety and Expedition? How can the Brains contribute to Operations of so fine and subtil a Nature? Are these Things then only in the Mind; in the purest Intelligence? Can you let us into that Secret, ye great Philosophers, that have studied and sifted Man to the Bottom? Here you scorn to dwell upon the Goodness of the Gift, or the Intention of the Benefactor: For you think that no Philosophy. Of all the Faculties that help our Thoughts, Memory is, in your Opinion, the grossest and the most material. It is essentially no more than a Matter apt to receive a Variety of Impressions. What produces Memory, is only a Stream of Animal Spirits, which imprint their own Stamp more or less deeply in that Matter, according as they are more or less abounding. They form a Picture there; and when new Spirits run into the same engraved Strokes, the same Images offer themselves to the Mind again. Nothing can be more plain or natural.

From the positive Manner in which you thus explain yourselves, one would be apt to think, that you have at your Disposal these Animal Spirits, the very Channels thro' which they run, and all the Vessels that convey them. As if you could dissect Memory. But, 'tis all Illusion. When I talk of the Superiority which Memory gives to the human Understanding, over that of the Animals; I speak, 'tis true, as one whose Knowledge is but very nar-

row,

row, ſince I only ſay what I know, and what every Body may very eaſily know of the Matter; but this Obſervation of mine is at leaſt connected with Realities, and may work upon the Mind, by filling it with Gratitude: Whereas when you materialize Memory, and learnedly articulate the Eſſence and Operations of it; you talk with Confidence of a Thing which you have no certain Idea of; and by that Means leſſen the Eſteem which one might otherwiſe have for your Diſſertations.

You know that the Rays of Light, being reflected from the Surface of Objects, paint the Image of the latter at the Bottom of the Eye. I will allow you to ſay (although you know nothing of it) that another ulterior Image of them is immediately formed in the Brain: But, were you as ſure of that as you are uncertain of it, there would be an Analogy, I ſuppoſe, between this laſt Image, and the ocular one; and as the Picture drawn by the Extremities of the Rays, at the Bottom of the Eye, laſts no longer than the ſhaking of the optic Nerve, it will be the ſame with the Picture which is ſaid to be drawn in the Brain. As ſoon as the latter ſhall ceaſe being ſhaken; the pretended Portrait which the pretended Animal Spirits had engraved in it, will vaniſh. What Picture can then remain in the Brain?

Beſides; what can the Image of a Savour be? What the Length and Breadth of a Sound? Could the Pencil of *Pouſſin*, or *Raphael*, repreſent the Smell of Jeſſamin, and diſtinguiſh it from that of a Roſe? Has a Colour any Outlines that can be delineated? According to what Direction muſt the Spirits ſtream in the Brain, there to draw the Purple rather than the Grain-colour. There is no Image but what has its Dimenſions. But the major Part of our Senſations, having no Lineaments or Dimenſions whatever; what can the Images of them be? And when the ſhaking of the Organs is perfectly over, how can there remain in us any Character or Figure of them caſt in a Mould?

I will not ſay, however, that there remains in us no Footſteps of what we have felt or thought; let People even affirm, if they pleaſe, that there remain in us Tracks and Images of all the Things we have experienced in the World. Theſe are looſe Words, that ſound indeed very learnedly;

but which teach us nothing in this, any more than in a great many other Matters. They are tolerated, becaufe they are employed by way of Metaphors, and cannot lead us into any dangerous Miftakes. But let us frankly own, that our Memory, as well as our Imagination, our Intelligence, and all the Things within us, is a marvellous Inftrument, which we employ without underftanding any thing of it; an Inftrument the more ufeful, as it performs Wonders, without our being troubled, in the leaft, with the Care of the Execution. The only Thing we are allowed to underftand clearly, in this noble Prefent made us, when we were endowed with Memory, is the manifeft Intention which the Creator had, to give Man Archives and Rolls, wherein he might depofit all the Records, and keep a Journal of all the Things he is concerned in. But to what Purpofe has God given him Regifters and Rolls, if not becaufe he defigned him to be a Governor?

MAN confider'd as GOVERNOR;

Proved from the Extent of his Will, the Freedom of his Choice, and the Direction of his Confcience.

DIALOGUE XI.

GOD has not only rendered Man capable of Knowledge, by inftructing him fufficiently concerning all the Objects that furround him, and by permitting him to inform himfelf of them more and more by new Effays and Trials; but he alfo allowed him the Liberty of appropriating the Ufe of them to himfelf: And, left he fhould give himfelf over to Idlenefs or Trifles, he infpired him with a prevailing and unconquerable Defire of being happy, which is the Spring and Principle of all his Actions.

His Activity, which renders him capable of thinking, projecting, and executing, and of applying the Organs of his

his Body to a Variety of Works, might flag, and, from a State of Laſſitude, ſink into a perfect Numbneſs; if it was not kept awake by a Love of his own Welfare. He is for ever in the Chace, and ſtops where he thinks he has found the Cauſe of his Happineſs. Follow Man in all his Motions; nay, in his very Indolence: You'll always find him ſetting out from that Point. Let the Action you ſee him do or avoid be what it will, the conſtant Aim of his doing or avoiding it, is the procuring of his own Happineſs. This leads the Son of *Philip* from the Streights of the *Helleſpont* to the *Granicus*: This makes him paſs from *Aſia* into *Africa*, from *Africa* to *Indus*, and brings him back from the *Indus* to the *Euphrates*. This the Son of *Pepin* aims at, when he goes from *France* to *Lombardy*, and from *Lombardy* into *Saxony*. 'Tis what the Son of *Hugh Capet* has fixed his Heart upon, when he employs all his Talents, and the whole Time of his long Reign, in making his Subjects happy by the maintaining of a durable Peace, and the reſtoring of Plenty in barren Years. It is the Hope of being happy, that renders the Learned greedy of Diſcoveries, and the Ignorant fond of Trifles. The ſame Hope animates the Artizan, who lends his Shoulders to the heavieſt Burdens, and the very Thief, who ſeizes the Property of others in order to ſubſiſt without Labour. This Love of our Happineſs or Welfare is then the Ground of all our Deſires, and it may be looked upon as the univerſal Spring which all Men are actuated by. Therefore our Will is the ſame with our Love of Happineſs.

Will.

But, notwithſtanding our being propenſe to our own Happineſs, from a permanent and unconquerable Impreſſion, yet we have ſtill the free Choice of the Means towards it. We carry our Eyes and Thoughts over all the Objects that ſurround us. The Pleaſure or Diſguſt which they give us, invite us to draw near or fly from them. Nothing in the World can either fill up or exhauſt the Capacity we have of deſiring and loving whatever can pleaſe us We may quit one Object for another, and go from Purſuit to Purſuit, from Project to Project, and from Trial to Trial. We may, likewiſe, from the bare Sight or Proof of one Good which offers itſelf to us, be ſenſible of its being abſolutely

Liberty.

neceſſary,

necessary, or barely useful, or perfectly insufficient, and accordingly be strongly inclined, or remain perfectly indifferent to it. It is this Power of Election which we call Free-will, or Liberty.

It may incline us, more or less, to certain Goods than to others, either by the Force of an Attraction that is present, or by the Ties of Habits contracted in Length of Time, or by an inward Conviction of having found the true Source of our Happiness; but in every one of these Cases, our Liberty is neither immutable, nor destroyed. It is never hurried away by any compelling Necessity, nor forced by any grievous Constraint.

Hitherto, all the Faculties which we observe in Man, are so many finishing Strokes of the Image of the Almighty in him. That Liberty, above all, is the Characteristick of his Sovereignty. For, as the Lord freely does whatever he pleases in the Universe, and rules despotick over the whole Universe, Man, likewise, has not only a Freedom of acting or not acting, but has also at his Disposal Animals, Plants, Fossils, and every Thing within the Reach of his Senses in his Habitation.

But, how much is it to be feared, that Gifts of this Nature will fill him with Pride, inebriate him, as it were, with his own Excellency, and make him less mindful of giving Glory to his bounteous Benefactor, than of pursuing his own Will and Satisfaction every where, or ready to admire himself on Account of what has been bestowed upon him! Will not God, who gave him but a limited Science, set Bounds likewise to this extensive Dominion? Shall he permit Man to lay Hands on all the Productions of the Earth, without Distinction; to pull down, consume, and make Property of what he pleases, without following any other Law but that of his own Fancy, or the Sense he has of his own Strength! Here we are going to see what God has inseparably united to Reason, in order to render the Dominion of it moderate, and prescribe a Rule to its Power, or keep its Desires under Restraint. God made Conscience, and an inward Sense of Order, the constant Companion of our Reason.

Conscience.

It may then be said again, in the truest Sense, that it is with the Liberty of Man, as it is with that of the Almighty. The latter never exerts itself at random, or unjustly:

juſtly: Wiſdom, and the Love of Order, are the Rule of all his Operations; and it was in order to give the finiſhing Stroke to his own Image in Man, that God rendered him capable of perceiving the Decency, the Proportions, the Moderation, Order, and Juſtice, which ought to attend, or rather animate all his Works. Man makes no Step or Action, but what has its peculiar Aim or Purpoſe; and he is conſcious that this Aim ought to be juſt and honeſt. He knows he has an Inſpector, and a Judge, that takes Notice of every Thing: and, leſt the Oblivion of God ſhould render Man unmindful of referring his Actions to their true End, or even capable of attempting every thing without any Diſtinction of Right or Wrong; God, together with the Senſe of what is good and honeſt, has placed at the Bottom of his Heart the Warning of his Conſcience, with Regard to which, Man may ſometimes lull himſelf aſleep, but which will not ceaſe, nevertheleſs, to ſpeak to him, and is a Faculty as imperiſhable as his Free-will, becauſe it is equally the Work of the Creator. If Conſcience has not always the Power over Man, to make him forſake his perverſe Habits, or put a Stop to the Effects of them; it diſturbs him at leaſt in his ill Practices: It forewarns him: It reſtrains him in the Middle of his Exceſſes. He carries every where within him, not only a Witneſs of all his Actions, but alſo a faithful Monitor, or even an impartial Judge, who commends him for all the Good he does, and unmercifully condemns thoſe of his Proceedings which are contrary to Juſtice or Truth. Whatever is true, juſt, becoming, lovely, or praiſe-worthy, his Conſcience ſecretly extols the Merit of it in his Eyes, and excites him to the Practice of it. Whatever carries with it the Face of Falſhood and Injuſtice, of Meanneſs and Indecency, of Unhandſomeneſs and Diſhonour, he never can conſent to it without being immediately reproached with it by his Conſcience. Its firſt loud Cry precedes the bad Action. If he then executes his ill Purpoſe, he does it with Anxiety; and, if poſſible, in the Dark. Or if the Voice of Conſcience is ſilenced by the Tumult of Paſſions that hurry him away; Conſcience, notwithſtanding his apparent Contempt of Juſtice at that Moment, will ſoon puniſh him for it, by reminding him of his paſt Villainy:

lainy: It gnaws him inwardly, by exposing before his Eyes the Detail of his Violations of the supreme Order, his inmost Intentions, the true Motives which he had disguised in his own Mind, and every one of his most secret Motives and Concerns.

This Cry of Conscience is heard every where: It is the same in all Ages, and among all Nations. The Abhorrence of Vice, and Apprehension of transgressing Order, have taken Place before all Laws, which are only more or less extensive Expressions of a common Law we all of us carry within ourselves. Edicts and Rules were as yet unknown at *Athens* and *Rome*, when Theft, Adultery, Infidelity, and Tyranny were already detested there. All the Histories that are now left of the most celebrated Nations or Men, are a Series of Upbraidings against Vice, and of Applauses bestowed on Virtue. What can that Concern be with which we read the Narration of Things so very foreign to our Manner and Affairs? It is indeed nothing more than the secret Judgment which our Conscience passes upon them.

Learning, Force, Industry, Eloquence, and all Talents in general, have been every where praised. They have been looked upon by all the World as an Emanation of the Divine Essence, or as a happy Participation of its Favours. But that which has at all Times been thought the Imitation, and the most perfect Communication of it, can be nothing but Virtue.

Man may improve his several Talents separately and without ruling his Affections. He may be a good Pilot, or an excellent Carpenter, without being a good Man. But the Love of Order regulates the whole Man without Exception. The Rectitude of his Will communicates itself to all his Faculties. It will not suffer any thing useless in him, and stedfastly improves all and every Part of his Government. The love of Order is then what brings him nearer to the Perfection of the Almighty; and a constant Virtue, I mean a constant Obsequiousness to the Dictates of our Conscience, and our natural Sense of Right and Wrong, is the most lovely, and the most sublime of all Things.

Such is the Sum of those of the Prerogatives of Man, which offer first to the Mind: Such are the first Characteristics

teristics of his Resemblance with God. If God has done even much more for Man: If he has prepared for him a State of Perfection incomparably superior to what we have seen; it will then be Time enough to examine and enquire into our Hopes, when we come to his Quality of Worshipper, and the Privileges annexed to that Quality. But his Government is so honourable a Post, that we ought not to be contented with having seen it only in a general Manner. It is both just and delightful to know the Extent, the Obligations, and the happy Effects of it. Let us all of us learn the Art of governing.

The Execution of whatever Man directs and produces, depends upon the Ideas and Rules which he has made himself sure of by sufficient Trials, in order to form the Body of his Science of them. Let us now, with some Leisure and Care, discourse upon the finest Inventions of Man. We shall lay aside pretended Sciences, imaginary Knowledge, stately Researches, and all the Promises of Discoveries that have proved abortive. We shall still more carefully shun that gloomy kind of Metaphysics, which takes upon it peremptorily to decide every Question, because it can create Difficulties upon every Thing. An unhappy Fruitfulness this, which ends commonly in rendering intricate, and at last eclipsing the Dignity of Man, so as to make him, like the Beast and the Insect, no more than the vile Inhabitant of a lurking Hole, a Den, or a Hive.

We shall take for our Topick that Science which is most known and general; that which borrows its Praise from its Effects; that which procures on Earth some real Good which Mankind is actually possessed of; that, above all, which commands and encourages all the Works of this Life from the sensible Conviction of one to come. I am persuaded, my dear Friend, that you approve very much of this Choice of mine, and that I need not make any Apology for it. What I here promise you, may be called History of Reason. I shall not swell it with the con-dictory Opinions of the Philosophers, because I pro-ed you, from the Beginning, to follow Man; not in-d in his Errors and Mistakes, nor in the Attempt he is equal to, but in that alone which is truly noble and va-

 luable

luable in him. I rank in this Claſs the real Improvements of his Underſtanding, and thoſe experienced Methods by which he learnt how to govern every Thing upon Earth.

Of uſual SCIENCES.

The uſual LOGICK.

DIALOGUE XII.

IF I preſent you here, Sir, with a Logick different from all the Logicks you know; it muſt needs be becauſe I look upon it as a good one. But when I praiſe it with ſome Confidence, it is only becauſe this Logick is none of mine; it is becauſe I had it from all the People of good Senſe who in paſt Ages, as well as in this, have diſtinguiſhed themſelves from the reſt of Mankind by an Accuracy and Judgment univerſally acknowledged and applauded.

There are a great many Things true and well grounded in *Ariſtotle*'s Categories, in the *Organum* of Chancellor *Bacon*, in *Deſcartes*'s Meditations, in the Logick of *Clauberge*, in the Art of Thinking of *Port-Royal*, in *Crouza*'s Syſtem of Reflections, in *Locke*'s Eſſay on human Underſtanding. But, the good happens to be mixed there with Reſearches which the moſt judicious of theſe Authors generouſly adviſe us to omit, as not being very neceſſary. In the abovementioned Meditations and Eſſay, the Good proves to be mixed with Hopes and Promiſes which the Event has demonſtrated to be frivolous*: Nay, very often with Thoughts fitter to lead us aſtray, than to regulate our Conduct. Two or three Inſtances of the latter Kind will ſuffice to give you the Notion of a Logick which Mankind may very well do without.

* See *Hiſtory of the Heav. Vol.* 2.

" *Locke

"***Locke* maintains, that whatever is inconsistent with "such Decisions of Reason as are clear and self-evident, "ought not to be insisted upon, or admitted as Matter of "Faith."

Here is then, first of all, the discerning of what we are to reject or receive in Point of Faith ascribed to Reason, as the peremptory *Judge* of the Matter. Hence the final Judgments of all those clear-sighted Reasons, which, tho' they never cease to contradict one another, yet if you will believe them, never utter any but clear and self-evident Decisions.

The Maxim here given us for the Rule of our *Christian* Profession seems not to be very fit to make *Christians*. When uttered by a Man who gave himself once for such, how can it be made to agree with St. *Paul*, who will have us captivate our Understanding, and bring it under the Yoke of Faith, and admit of the Sacrifice of a Messiah upon a Cross, although our Reason *judges* it a *Madness*, that is to say, a Tenet inconsistent with what Men fancy to be perfectly clear and even self-evident.

St. *Paul*, 'tis true, will have our Obedience to Faith be reasonable, because nothing is so reasonable as to keep to the Certainty of sensible Testimonies, and of Facts of which the Proofs are in our very Hands, and before our Eyes. But St. *Paul*, nor any of the first *Christians*, ever acknowledged Logick which submits Faith to the *Decisions* of Reason. Their Logick, on the contrary, was to make themselves sure of Revelation by the Concurrence of Witnesses, and to look upon that Revelation as the Supplement, the Help, the Rule, and Glory of Reason.

The same *Locke* advances with Justice, and according to universal Experience, that our Knowledge lies within a very narrow Compass: But he thinks us short-sighted so far as not to be able to distinguish, by the Difference of the Sentiments and Effects, our Soul from a Body, as we very well distinguish Air and its Properties from Water and Nitre by discerning their sensible Effects, although we have no manner of Knowledge of either of these three Bodies. Again, he thinks us dull to such a Degree as not to know whether a Lump of Matter, a rough Piece

* *Pag.* 573. 2 *Edit. Amst.*

of Marble, a Pumpion, but above all a Body diſpoſed in the manner of the Brain (although he knows the Brain much leſs than he does a Pumpiôn) might not have the Power of Thinking, Perceiving, Judging, and Reaſoning. This is a new Piece of Logick, ſtill liable to be controverted, and the Generality of Readers deny it not only as a diſputable Point, but even as a monſtrous Abſurdity.

One is much ſurpriſed after that, that a Man who extenuates and materializes Reaſon ſo far as to confound it with a Lump of Mire, or a ſmall Vortex of Duſt, ſhould dare to place that Reaſon upon a ſupreme Tribunal, there to judge peremptorily of our Faith, and determine what God ought, or ought not to have propoſed to us as Matter of our Belief.

How ſtrange ſoever that *Chriſtianity* and Conduct muſt be that have ſuch a Logick for their Rule; all we ſhall ſay againſt the latter is, that it is very far from being inconteſtable, and that this Logick, and all the others, are not abſolutely neceſſary. What we are now looking for, is a Way of Reaſoning, that may at once ſpare us long tedious melancholy Studies, and lead us to common, and as it were palpable Truths, both in Point of Buſineſs and with regard to Sciences and Revelation.

We know a Multitude of Writers that are dead, and a great many People now living, that have acquired much Honour by an uncommon Exactneſs in Point of Reaſoning, and by eminent Succeſſes of all Kinds, without ever having ſo much as looked into the abovementioned Logicks or any other Book of the Kind. Go and propoſe Rules and Methods to that Counſellor, whoſe Eloquence is generally admired at the Bar, or to that Merchant, who has acquired a vaſt Reputation for Judgment and Integrity: They will tell you that there is no need of keeping them in ſwaddling Clothes, ſince they know how to walk. But are thoſe excellent Genius's, who thus frankly own their being perfect Strangers to Logick, altogether without Method? Far from it. Nay, we might make very good Methods and true Syſtems of Logick, by reducing into Maxims what we hear them ſay, or ſee them do. All thoſe who have thought right and met with good Succeſs in all Ages, by

the Soundness of their Judgment, have had an excellent Logick.

'Tis that Logick that governed the Execution of the Projects of *Julius Cæsar*, and disconcerted those of the *Gauls*, always at Variance with one another. 'Tis the same that regulated the Precautions of *Charles* the Wise, and the Campaigns of the judicious *Turenne*. 'Twas this Logick which inspired the great *Colbert* with the Taste of good Establishments: 'Twas that which guided *James Cœur* and *Antony Crozat* in the several Undertakings of their Commerce. 'Twas the very same Logick that enabled *Horace*, *Vida*, and *Despreaux*, to supply us with infallible Rules upon the Art of Writing; the same, in short, that guided *Tully*, *Quintilian*, and *Rollin*, in the best Things they have said concerning Eloquence and the Culture of the Mind. If our great Ministers, our skilful Civilians, our famous Orators at the Bar, and our wealthiest Merchants are able by Word of Mouth, or in Writing, to clear the most intricate Affairs, and ingeniously to prevent the Consequences of unforeseen Accidents; it is only because they reason well. Which is then their Logick? If they have one, we need not have another; that being at least surer than any other.

Every one is able to consult printed Systems of Logick, and to pick and chuse the Good that may be in them. But, lest we should take for Rules the false Opinions they may contain, or miss the Truth out of Deference for celebrated Names, let us make sure of that Logick that has formed or guided all great Men. The whole of it may be summed up in the following historical Maxim:

All prudent Men that have taken a wise Course and made a proper Choice in Point of Science, Business, or Religion, arrived at the Knowledge and the Kind of Certainty which suited their Situation; first, because they built upon what was well tried and sufficiently ascertained; and in the second Place, because they made Use of what was tried and attested to arrive at what they knew not.

Such is the abridged History of their Prudence; and in some Sense the History of Reason. Such is in good truth our usual Logick, as well as that of past Ages. We daily exercise ourselves in it, and think of quite another thing than Logick. Every one in his own Condition learns

how to think right, by using himself to Observation, Reflection, and Reason. How many Officers and Ladies there are who daily arrive at a wonderful Degree of Exactness by this habitual Method, without knowing that it is a Method?

We may make this a Kind of reflected Study, by prescribing to ourselves a Number of Maxims, grounded upon the natural Bounds of our Understanding, and the good or bad Success of our Experiments. The Benefit of this Logick will be so far certain as it will incline us the right Way, and confirm us both in the Enjoyment of the Advantages generally granted to the human Understanding, and in the actual Exercise of our acquired Talents.

The first Part of the usual Logic consists in knowing what it is we understand by a well tried Matter of Fact; the second consists in knowing how we ought to pass on from known to unknown Truths. There is no need of any Masters or Books to succeed in either of these Points.

PART I.

Sensible Proofs, the sure Foundation of our Knowledge.

THERE are numberless Questions, the Solution of which we vainly expect from God, from Reason, from our Senses, from all Nature and Society. We never obtain any Answer concerning them; or if we fancy that Answers have been given us; other Speculators pretend that they have received quite contrary ones. Both Parties exclaim and plead that they alledge none but the Decisions, nay, the clear and self-evident Decisions of Reason. Hence Disputes and all their Consequences, the least of which is very often their Unprofitableness, or the Vexation of not knowing at last what to fix upon. Such is the Question of the Species and Figures of the first Elements which Bodies are composed of.

If there are Branches of Knowledge altogether inaccessible to us, shall we attempt to force a Passage that way?

Let

Let us rather consent to renounce it without murmuring. But, if there is a Kind of Knowledge that we can attain to, and lay hold of as it were with our Eyes or Hand, that will be our Lot, and will become dearer in Proportion, as it is more useful to us. Now, what surer Sign of an easy Access to any Truth can we have, than the sensible Experiment we may make of it, or the never-failing Effects that correspond with it. That Experiment is a surer Mark to discern Truth by, than the Touch-stone is to distinguish Gold from any other Metal.

Doubtless God might have busied us upon none but purely intellectual Subjects, or have laid every Truth open before our Eyes without Clouds or Mystery, without any Relation to sensible Objects, or any corporeal Mixture whatever. But he has not done it: And who shall dare to say to him, " Why didst thou not place me at once " in the Sphere of the spiritual Intelligencies? When " thou lodgedst my Soul in this material World, didst " thou propose to degrade or fling it into a Lump of " Mire?" Let us look with Scorn upon these unworthy Murmurers, who dishonour their Reason by Blasphemies, much more ridiculous than dangerous.

It was not without some very great Views, that God thought it proper to bind up our Minds with so many different Ties to the material Objects that surround us. He has thus effected his set Purpose, which was, that we should make part of this transitory Society, to supply the Matter of our Works and exercise our Virtue, in Expectation of another Society, which he at present gives us but the Hope and Foretaste of. In all the different Helps wherewith his bountiful Providence has deigned to honour and assist Man, such as his Senses, Reason, Conscience, the Hope of a better State to come, and the inestimable Gift of Revelation; God proves invariably faithful to his Plan, which was to link Man with Man, and hinder them from going out of that Society, by rendering it necessary to them, for the Supply of their respective Wants, for the learning of general Truths, or those necessary to our Salvation.

He makes them experience at the Bottom of their sound Reason Glimpses of Truths, which are only hinted to them, and Desires of Perfection, that fill them with

Activity. But if they are too desirous to get out of the Dark, he leaves them in it; it is in the Society of other Men, that they look for and never fail to find the Footsteps of all necessary Truths. As God was not willing that they should accustom themselves to a Way of Thinking and Acting, that would make them a set of proud Logicians, of self-conceited Wits, of scornful Man-haters, fond of living retired, and far from the common Occupations of Mankind; He causes their Uncertainty to increase, and their Darkness to redouble in Proportion, as they strive more and more to raise themselves above their Senses, into the Region of what is purely intellectual. All those who have attempted to soar up so high, fell to the Ground most ignominiously: Whereas God procures a true Sense of Things, Security, and the Enjoyment of their Effects to those who stedfastly confine themselves to sensible Experience.

You will not suspect me, my dear Friend, of Meaning by this affecting and sensible Experience, peculiar Fancies, Chimera's, Raptures, and personal Evidences, which are luminous to none but ourselves. We shall avoid, with the utmost Care, the Behaviour of Fanaticks and Enthusiasts; who mistake the Sickness, or Disorders of their own Brain, for so many Communications of the Divine Spirit, or their peculiar Fancies, for the Dictates of Reason. It was, on the contrary, in order to preserve us from these imaginary Illuminations, and to warn us against all pretended Evidences, and deep Sciences, that God subjected us to a common Method and Course, by making our Certainty, and our well grounded Security, to depend upon the Experience of our Senses.

I call sensible Experience or tried Evidence, that which manifests itself by an uniform Impression in the Operations of Men, and which corresponds with our Ideas, by never-failing Effects.

1. Such is, in the first Place, the Impression which Numbers, Proportions, and Measures, make upon us. They are Relations that prove the same, and are perceived and consented to every where. We never question any but those that are too complex.

In *China*, as well as in *France*, the Gardener who causes a stretched Line to turn round a Pin stuck in the Ground,

Ground, and the Geometer, who makes one of the Legs of his Compaſſes turn round the other Leg, fixed to a Point, are both equally ſenſible, that all the Points of the Circle drawn, are at the ſame Diſtance from the Centre, becauſe that Diſtance in a ſtreight Line is always either of the Length of the ſame Line, or of the ſame Opening of the Compaſſes. It is experimentally and univerſally true, that the Diſtances in a ſtreight Line, that tally with a common Meaſure, are equal to one another. God alone contains this and all other Truths, ſince they are as immutable and eternal as he is himſelf. In what Manner he ſhews them to us, I indeed know not: But it is his Will that our Senſes ſhould put us in the Way of perceiving them. I know not how they affect my Mind, or become viſible to it: But all Men conſent and agree, that their Senſes make this Truth palpable to them, that Diſtances in a ſtreight Line, that are equal to common Meaſure, are equal among themſelves.

2. Another Kind of univerſal Impreſſion, that proves the ſame every where, is the inward Senſe we all of us have of our own Thought, of our Body, and thoſe that ſurround it, of that undeſignable Power, that communicates to us with ſo much Elegance and Order, the Perception of one and the ſame Sun, of the ſame annual Revolutions, and of the ſame Univerſe. Is there any one of us that has not a thorough Senſe of the Thought or Reſolution that fills up his Mind, and of that active Principle that renders him Maſter of his own Body? Who is the Man that will ſeriouſly doubt the Exiſtence of his own Body, or that of the Earth and Heavens? Where is the Perſon that does not feel the Influence of that ſupreme Cauſe that makes upon us, and in ſpite of us, conſtant Impreſſions that are regularly repeated? Let us be willing or not, to call that Cauſe by the Name of God, we do not receive his Favours a whit the leſs for that, nor are we leſs conſcious of his Influence on us, and of our Incapacity of avoiding that Influence.

Let us diſperſe all the Inhabitants of *Paris*, a Million of Men, all over the Plain of *Grenelle**: The Dome of the Invalids acts upon none of them, and yet there is room to think, from the uniform Manner in which they ſpeak

* A vaſt Plain near *Paris*.

of it, that they all see it in the same Manner, even to a Man, and that one and the same Cause affects them all round, with the very same Dimensions and Colours, in short, with the self-same Perceptions. A few of them only, that are more skilled in the Practice and Discernment of Proportions, will perceive apart, and easily make the others sensible that there is not Symmetry and Harmony enough between the Mass of that large Body, and the Slenderness of the Piramid that terminates it; between that magnificent Support, and the small Spire it sustains. Such are the Ideas that strike and make them all unite in one Opinion. That Dome has no Power over them. There is then a Cause which uniformly imprints upon every one of them regular and constant Sensations, that make them speak in one and the same Manner. Let that Cause be called God, or have any other Appellation whatever: It exists: It acts powerfully and regularly: It communicates itself to that Million of Souls, and is the true and only Bond that can thus unite them together.

Those Ten hundred thousand People, are then equally sensible of their own Perception, of their own Body, of the other Bodies around it, and of that identical Cause which operates in them, and in Spite of them, that Uniformity of Perceptions at the Appearance of all those Masses that are destitute of Life and Action.

Those who are deprived of some one of their Senses, for Instance, of Sight; have no manner of Notion of what has thus affected the others in this Plain. Although, therefore, there is a common Principle of these universal Impressions, that Principle does not generally communicate them otherwise than by means of the Organs of our Senses. Whence it follows, that our Knowledge increases and diminishes, Hand in Hand, with our Senses.

3. There is a third and universal Impression of the Influence of God, upon us, *viz.* the Knowledge which Man has of the Injustice that would be done him by taking from him either his Life, or the Means of preserving it, or the Enjoyment of the Fruits of his Labour. Were he alone on the Earth, he would not so much as think of these Things: But, being here with others that can hurt and wrong him, the Injustice he is afraid of informs him of the Injustice he might be guilty of against his fellow-

Crea-

Creatures. 'Tis true, the Inspection of the *Meum* and *Tuum*, is not the Speculation of Justice: But God manifests the first Principles of Justice to Man, on account of his Wants, and by the Ministration of his Organs. Nothing can be more wisely established than this Order. If Man was immortal, and had been placed in a Planet where he did not perpetuate his Species by Marriage, he would have no Idea of the Excellency of Chastity, nor of the Turpitude of Adultery. And really, why should God impart to him Truths and Principles that would be of no Use to him? On the contrary, if he was indowed with a sixth Sense, he would know a new Class of Duties that would regulate the Use and condemn the Abuse of that Sense. It is then in a Manner relative to his several Wants, that Man finds himself inclined to the Observation of the immutable Principles of a Set of Morals that regulates his Condition. A Man who becomes an Husband and a Father, knows what he owes to his Wife and Family. How and where does he see the Principles of his Obligations in *Europe* as well as in *America?* We indeed know it not: But, he sees them because he is a Husband and a Father.

These Principles proceed from a common Source, as Colours do. God alone contains immutable Truths, and shews unchangeable Colours. But, if Man is deprived of the Use of his Senses, God does not communicate to him a certain Class of Truths which other Men see, nor a certain Number of Colours which other Men know. Although then our Senses can produce neither Colours nor Truths, yet it is the Will of God that our senses should serve to make us perceive them. Our Senses have not the Discernment of Truth in themselves: But they turn our Reason towards that universal Truth which has Relation to the Things that strike us We were made such by the Creator: Such is the Order of God himself. All we are to do is to follow that Order, without ever losing ourselves in an Abyss of Speculation concerning the Origin of our Ideas. Such a Study is far beyond our Reach.

4. Besides the Esteem we ought to have for the separate Advices we receive from every one of our Senses, we cannot dispense with observing and admiring how they mu-

tually help each other, and jointly contribute to make us arrive at the Knowledge of the Truths that are of Concern to us.

Man, very often, ſtands in need of knowing more than he can actually learn by the Aſſiſtance of his Eyes. He would fain be informed of what paſſes beyond the Reach of his Sight, or be acquainted with the Tranſactions of remote Ages. He is ſometimes at a Loſs how to diſcern what is juſt from what is not ſo, as the Caſes he is in are more or leſs complex, and the Application of ſimple Rules more or leſs puzzling and intricate. He wiſhes for, and has already a Glimpſe of a Life, wherein Vice and Virtue may be requited in a Manner altogether different from what they experience here below. God has provided Means to relieve him of all his Perplexities. His Senſes help him to learn what his Reaſon does not teach him: What one of his Senſes cannot tell him, he diſcovers by Means of another. Many of his Senſes, will often combine their various Advices towards finiſhing his Conviction. But when neither his Reaſon nor his Eyes can inform him of what paſſes in other Places, or of what was tranſacted formerly, his Ear comes to his Aſſiſtance, and inſtructs him of every thing by Recitals, Atteſtations and Embaſſies: Nay, his Eye, his Ear and his Hand, will oftentimes witneſs the ſame Things to him.

Thus is Man indebted, not indeed to his Reaſon, but barely to his Senſes, and above all to his hearing Faculty, for the Knowledge of what is of Concern to him in foreign Countries, and for the Knowledge of Hiſtory. His Ear, in ſhort, is the principal Organ by which God inſtructs him in the revealed Morals, and in all the Truths that fix his preſent State, and procure his Salvation. Doubtleſs our Eyes, and with ſufficient Witneſſes, may by their combined Authority, give a new Sanction to the Atteſtations of our Ears: But, as a Legation is the Means by which we are informed of the Alliance a foreign Prince is diſpoſed to make with us, we have likewiſe been appriſed of what we are to believe or practiſe towards being ſaved by a ſenſible and immortal Embaſſy, that has been directed to us to reveal the Things that could not be found in our Reaſon.

Wiſdom

Wisdom and true Logick do not consist in taking for our Guide and Rule, a Reason which has no Knowledge of its own that can be sufficient; but in preventing the Mistakes, and fixing the Anxieties of our weak Reason, by the Simplicity and Certainty of the sensible Means which God supplies us with, of strengthening and acquainting it with every Truth that can be necessary.

Let us make a short Recapitulation of them.

The Uniformity of such Relations and Measures as are constantly justified by an eternal Repetition of the same Effects. The first of these universal Means, is the Source from which we draw our speculative and practical Mathematics.

The Sense of our own Soul, of our Body, of other Bodies round it, and of that Cause which conveys the unavoidable Impression of them upon us all. The second of these universal Means, is the Source from which we draw all the Knowledge we can possibly have of Nature, and a modest Metaphysics, that distinguishes Beings by their respective Effects, without presuming to penetrate deeper into them.

The Sense of what is due to us, and of what is reciprocally required of us by our fellow Creatures This third universal Means is the first Source from which we fetch the Rudiments of Morals and Equity.

Lastly, *the sensible Experience of those Monuments, and Testimonies, and that uninterrupted Legation, which from Day to Day brings us the good News of our Salvation.* From this fourth universal Means of instructing all Mankind, we have the only sound and solid Theology, and a full Knowledge of Faith and Morality.

By thus referring to Experience and convincing Testimonies, the Study of Society, of Nature and Revelation, we fix our Reason in the Order which God himself has established. We proceed from Light to Light: We arrive at what is certain, and nothing is more capable than a Method so easy and so suitable to our Condition, to fill us with comfort in our Troubles here below, and with Security concerning the Choice of the Course we are to follow in our Search after Truth.

The first Part of our universal Logic will then consist, for the Learned as well as for the Ignorant, in acknowledging

ledging how weak our Reaſon is when deſtitute of Aſſiſtance; and in acquieſcing in the tried Methods which we have received towards ſupplying it with the Helps it ſtands in Need of. But theſe Methods muſt be applied to their proper Uſes; ſo that the ſecond Part of our Logic muſt of Courſe turn upon the Manner of imploying what we know already, to arrive at the Knowledge of what we know not. The firſt Part puts all Men indiſtinctly upon a Level; their Reaſon being equally dark and gloomy. But what diſtinguiſhes the good Logician from the common Man, is the right Uſe of the ſenſible Means which Reaſon has received of procuring its own Inſtruction and Improvement: And in this Logic, the moſt preſumptuous among the Learned always proves the unfitteſt to become a true Philoſopher, as his Perſuaſion of finding in his helpleſs Reaſon, what God forewarns him to look for ſomewhere elſe, is the directeſt Means for him to miſs the Truth he inquires into.

PART II.

The Uſe of Senſible Means, and the Exerciſe of our Reaſoning Faculty.

THE Perceptions which we have of Things, and of their Qualities, what we experience from the Teſtimony of our Senſes, what remains of that Teſtimony in our Imagination and Memory, in ſhort, all the Objects of our Thoughts are called *Ideas*. Theſe Ideas joined together, are the Pictures as it were, of the Things within and without us. They are true and well combined Ideas, when they anſwer exactly to the Things they repreſent, and have among them the ſame Order and Relations which are in the Things themſelves. For we compare many Ideas together, and we judge whether one is connected with or exclusive of the other. We likewiſe compare ſeveral Judgments one to another. We draw them near each other, in order to throw upon that which was obſcure, the Light we perceive in another Judgment that ſeems to have a Connexion with it: And we thus become by Degrees more and more certain of the Exactneſs of our Thoughts, in Proportion as we experimentally find the Things

Things themselves ranged without, in the same Manner we have conceived them within us; or when we see our Conceptions justified by regular and constant Effects.

Man may exert his reasoning Faculty, either upon abstruse and purely intellectual Ideas, or upon practical Objects that are of common Use in Society. Here is a reasoning of the first Kind. He knows not, for Instance, the Relation which is between the Quantity X and the Quantity A, nor the Quantity B joined to the Quantity C. But he knows on the one hand, that A more B, more C, is equal to D diminished by the Quantity E. He knows on the other Hand, that D less E is equal to X. Whence he infers that A more B, more C, is equal to X.

But these Reasonings, which he makes upon Objects so very remote from the Senses, are apt by their Coldness to chill his own Mind, and contribute but very little to render him useful to others. 'Tis true, we are now considering Man by himself, and exclusive as it were, from the rest of Society. But he is preparing to enter into it: This is indeed his necessary Condition. He will then do very well not to learn the Art of Reasoning, purely to know the Apparatus and Process of Reasoning; but he will learn the right Way of using his Reason, in order to fulfil his Vocation, and be useful to others by the improving of his own Mind. It is plain that he will procure their Good and his own in Proportion, as he takes Care to exercise his Judgment upon common Ideas, and constantly to pursue that Kind of Certainty, from which something practical may result: He is sure by that Means of becoming equally agreeable and useful to Society.

Nevertheless, if he is bent upon having Ideas of his own, it is by no means an Impossibility. But let him then, in that Case, go to another World that his Notions may be worth something there, or let him expect in this to be looked at as an Inhabitant of the Planet *Jupiter*, or as some Animal fortuitously escaped from the Moon. A Man determined by Algebra or Metaphysics, would no longer be one of us. Such a one is by no means the Man we are looking for.

The Organs Man is provided with are so exquisite, that the Use he makes of them may serve him in the room

room of Inſtructions. A great Maſter in point of Eloquence, and a good Maſter of Muſick, when they have a Mind to produce all the poſſible Sounds and Articulations of the human Voice, never enquire into the Structure of the Trachea, or the Action of the Tongue, or the Concurrence of the Teeth, the Lips, and the Roof of the Mouth. Such an heavy lingering Method would be of no Service to them. They propoſe to their Diſciples, Models of Eloquence and Melody. They begin by executing their own Preſcriptions themſelves, and their Diſciples, as well as they, learn how to ſpeak or ſing elegantly, not by meditating upon Voice, but by ſinging and ſpeaking. Reaſon is a moſt exquiſite Inſtrument given to Man to render him ſociable. It can never improve by ſhrinking back on itſelf, or endeavouring to inſtruct itſelf by withdrawing from Society. Man ought rather to chuſe the Objects the moſt ſtriking in Society, to improve his reaſoning Faculty by them; becauſe he retains them with more Eaſe, Satisfaction, and Profit. He was born for that Purpoſe.

For Inſtance, he caſts his Eyes upon two great Habitations of Men, that remain ſtrictly united, from the Neceſſity of being of mutual Help to each other. It is a Maxim in one of the two, never to admit of more than two Claſſes of Citizens, *viz.* Warriors and Huſbandmen; becauſe they look upon them as ſufficient to obtain the Products of the Earth, and ſecure the Enjoyment of them to themſelves. The other Republic adds to her Soldiers and Ploughmen; a third Claſs of Inhabitants, which is compoſed of navigating Traders, who carry the ſuperfluous Part of their native Productions to foreign Countries, and exchange them there for other Commodities which they think neceſſary, or at leaſt advantageous. *Lacedæmon* is the Habitation of the firſt Kind: *Carthage*, of the ſecond. If Man has it in his Power to fix his Choice, and become a Citizen of one of the two, which of them muſt he prefer? This is Matter of Deliberation. Let us now conſider the ſeveral Steps of his Reaſon, without anatomiſing Reaſon itſelf.

He does not queſtion, in the leaſt, the Neceſſity of having Ploughmen and Soldiers in the Republick: But the Uſefulneſs of the Navigators is Matter of Heſitation. They are not very certain, whether the Idea of publick Happineſs

neſs ought to be united with, or ſeparated from that of foreign Commerce. The Mind has then Recourſe, in this Dilemma, to well-known and well tried Ideas; which being agreeable to public Good on the one Hand, and to foreign Trade on the other, may ſupply him with a Motive for reuniting the two, concerning the Connexion of which he is ſtill in Suſpenſe, that is, with a Motive of affirming poſitively, that the Idea of publick Good ſquares and tallies with that of foreign Commerce.

The comparative Ideas here meant, the well-known and generally tried Ideas, which muſt fix the Uncertainty of Man in this Caſe, are the following.

1. Improving to the beſt Advantage Things that would prove uſeleſs, ſuch as Iron, Flax, Wood, ſuperfluous Quantities of Corn, or other Proviſions, that cannot be conſumed.

2. Repairing by Exchanges, and to a conſiderable Profit, the Diſorders of Seaſons, the Havocks occaſioned by War, and the unavoidable Loſs of a great many neceſſary Proviſions, or the Smallneſs of our native Commodities.

3. Employing in great Forges, in Rope-yards, in Manufactures of Linen Cloth, in Arſenals, in neceſſary Tranſportations, and in the actual Service of Fleets, a Multitude of Men, and Beaſts of Burthen, which otherwiſe muſt periſh for want of Occupation and Salary, or conſume a World of Proviſions without being of any Uſe, and conſequently ſtarve thoſe who work for a Livelihood.

4. Facilitating by the Charms of Liberty, of buſtling, and of the Proſpect of a great Fortune, the Removal, and oftentimes the total Reformation of idle, uneaſy, or untractable Citizens.

All theſe Ideas, and others reſulting from them, are perfectly connected with the Happineſs of a Republic, of which they are the Support and Reſource. On the other Hand, the ſame Ideas have a palpable Connection with that of foreign Trade. This ſingle one implies all the others: And by means of theſe intermediate and univerſally tried Ideas, the human Mind is gradually authorized ſtrictly to connect the Thought of publick Happineſs with that of foreign Trade, which was not perceived at firſt Sight.

After this Examination of the Superiority of *Carthage* over *Lacedæmon*, it may be made a Question in the former of these Towns, which is best, to let Commerce be free to every private Man, or to put it entirely in the Hands of a Company of Merchants, with a Prohibition to other Traders, of ever meddling with it.

Let us, on this Subject, listen to a *Grecian* Philosopher, who was naturalized at *Carthage*, where he could not be admitted as a Citizen, but upon Condition that he would confine himself to what is merely useful, by reducing his Philosophy to Geometry, Mathematics, Navigation, and Natural History. This Philosopher is a Logician, and he intends to teach his Disciples the Art of Reasoning, but instead of proposing to them an abstruse Logick, that would cause his School to be deserted, and besides set him at Variance with the Magistrate, he borrows from Trade itself, which he is a Master of, and from the reigning Taste of the Nation of which he is become a Member, the Examples of the Method he teaches; being persuaded that the Habit itself of Reasoning, and frequent Models of good Arguments are the best Instructions in Points of Logick.

I am asked, says he, whether I must connect the Idea of publick Good with that of a free Commerce, given up to every private Man without Reserve. But, I reply first of all, that this Notion of Commerce is too vague and too general. It takes in too many different Matters and Countries, to become the Object of a Judgment liable to no Mistakes. For, what can be said with Truth of a Commodity and a certain kind of Trade, is not equally true of all the others, since the Ways and Profits of Trade vary as much as the Matters that are transported, and proportionably to the Exigencies or Tastes of the several Nations we are to deal with.

The Commerce of our *African* Commodities may be considered separately from foreign Trade: And in this last, the Nature of our Affairs in our Colonies of *Sicily* and *Sardinia* may be very different from the Commerce which our Navigators carry on in the Fortunate Islands, and with other Strangers who are not our Subjects. Now, this makes three Questions out of one.

First,

First, whether the Idea of publick Good is inseparably connected with the Sale of our Corn and Oats, granted in a special Manner to a certain Company of Merchants, exclusive of all the other Citizens?

Secondly, whether the Idea of publick Good may be easily reconciled with that of a Commerce entirely free in all our Colonies?

Thirdly, whether the Idea of publick Good is compatible with the free Commerce of private Traders in Countries that are remote and independent on us?

As to the first Question, which is, whether it is for the publick Good to oblige all our Farmers and Landlords, to deliver up at a small and uniform Price, their Corn and Oats into the Granaries of a Company that will engross the Sale of them in an exclusive Manner? the intermediate Ideas that come to our Assistance in the solving of it, are the following.

No Hope of Fortune whatever left to our Country-People. A total Extinction of all Industry and Emulation. A Difficulty for our Farmers to pay in the annual Rent in Years of indifferent Crops. The low Circumstances of Farmers, necessarily followed by the Ruin of the Artizans and Journeymen who get their Livelihood by them.

If the Company that makes this Sale is fixed itself to a small invariable Price, this Commerce becomes void of Encouragement and Activity for the whole Body of the Nation. Corn, which is easily preserved when in private Hands, is over-heated, and rots in public Granaries: A new Occasion this, for the exclusive Sellers to obtain the raising of the Price of Corn. This last Article being once granted to the Company, it has always some specious Pretence or other to prolong the Duration of the new Assise; and thus it crushes a Nation, instead of being an Help to it.

Experience comes here to the Assistance of Reason. No Country so thin of Inhabitants, and so poor, as those where Corn is kept in Reserve, and rated at a settled Price. The Peasants, thus deprived almost of the only Matter which can procure them Riches, make no manner of Expence. Now, where the Country spends nothing, the Towns must needs languish for want of Vend of Commodities: And it is what happens in those Places. The Countries are miserable,

ferable, and fill the Towns with People, who have no other Employment but that of begging.

All these Ideas, which are inseparably connected with that of the Commerce of necessary Commodities, carried on among us in the monopolizing Way, are, on the other Hand, inconsistent with the publick Happiness, and the Opulence of a Commonwealth. Therefore, publick Good, and the Trade of necessary Commodities given over to a certain Company, are Ideas mutually exclusive of each other.

Our above intermediate Ideas help us to see the universal Misery of our *Sicilian* and *Sardinian* Colonies necessarily connected with the Commerce of our native Productions and theirs, supposed to be exclusively centered in a certain Company. Our maritime Colonies are not different in our Eyes from our Provinces on the Continent. Our *Sicilians* and *Sardinians* are as dear to us as the *Carthaginians* of *Numidia* and *Bizacena*. Our Commerce is carried on with equal Ease and Benefit in every one of these Places. We know what passes there. We are timely informed both of their Superfluities and Wants, whereby to regulate the reciprocal Transportations of our respective Products. Thus we trade, with the utmost Facility, even in our remotest Colonies: And as the same Interest, and the same Wants, are common to them and ourselves, there ought to be the same Community in Point of Liberty. By destroying Liberty and Emulation, you ruin the Colony which makes one Part of the Republick, as well as one Part of our Revenues.

The whole Scene changes, as to the third Question. There is no Connection whatever between the Idea of publick Good, and that of the foreign Commerce to be carried on, for Instance, in *Albion* *, or in the Fortunate Islands †, by private separate Merchants, rather than by a wealthy Company that shall be well protected. Here are the comparative intermediate Ideas which naturally offer to the Mind on the Subject, and render the Union of the two former utterly impossible.

Never to be informed, in due Time, of what passes in foreign Regions, and of the Opportunities that may offer of

* *England*. † The *Canary Islands*.

making

making a considerable Gain. Never to be assisted or directed *bona fide* there, by any Person residing in the Place. To be ill served, on the contrary, and wronged by Disguises and false Relations. To strive to undo one another, not only by concealing the respective Transactions from each other, but also by reciprocal, jealous, or rather furious Out-biddings, that have no other Aim but the Ruin of such of the Concurrents who take it into their Head to over-rate the desired Commodity. To sink one's own Profit by bidding extravagantly. To break one's Obligations, for want of being able to retrieve an accidental Loss. The Dishonour and Discredit of the Nation in foreign Countries, occasioned by Bankruptcies, and by the want of Substance in private insolvent Traders. All these Ideas are inseparable from the foreign Commerce that is carried on by private disunited Merchants, or by unsubstantial and unprotected Companies. The same Ideas are strictly connected with the Disadvantage of the Republick, which loses at once its fugitive Citizens, together with their Advances, and its own Credit. I have then found in these comparative Ideas a common Measure, by Means of which I am entitled to pronounce, that foreign Trade in remote Regions, and among Nations that are none of our Subjects, will gradually decline, if it is freely carried on by every private Man; and prosper infallibly in the Hands of a wealthy reputable Society, all the Members of which are animated with the same Spirit, and able to repair its Losses speedily, by the Multitude of its Undertakings.

The same Truth may be treated Historically, because an unquestioned History is no way different from unquestionable Experience. *Carthage* having a Mind to draw out of *Laconia*, without much Expence, a Number of good Troops, which she intended to keep in Pay, in order to save her Ploughmen and Manufacturers, had engaged herself to supply the *Lacedæmonians* every Year with a certain Quantity of Wine, of Pewter, and of fine Wool, to be dyed in Purple at Cape *Tenarium* *. Our *Carthaginian* Navigators went and fetched, at a cheap Rate, the Wine of the Fortunate Islands, the Wine and Wool of *Bætica* †,

* *Now Cape Matapan, in the South of Morea.*
† *Andalousia.*

and

and the Pewter and Wool of *Albion*, which last is almost as fine as *Spanish* Wool. We were sure of having the necessary Recruits in due Time without interrupting the Culture of our Fields, or the Manufactures of our Stuffs, by any Levies of Soldiers; and we made our own Provision of Wine, Pewter, and Wool, with the utmost Facility, on account of both the Cheapness of these Commodities, and the considerable Valuation put upon them in *Laconia*, together with the Benefit of the Sale of the Overplus along the Coasts of *Greece*. But our Merchants being all of them willing to have a Share in the Commerce of these foreign Wares, had the Imprudence to over-bid them, in order to supplant each other; and having had Losses which they could not retrieve, they involved in their own Ruin a great Number of our Citizens, who had made considerable Advances to them. Our *Laconian* Provisions became chargeable to us, from the Habit Strangers had contracted with us, of selling them very dear. Then *Sichæus*, *Hanno*, *Adherbal*, at that Time the wealthiest Merchants of *Utica*, came before the Senate of *Carthage*, in order to obtain an exclusive Privilege for engrossing the Commerce of *Albion*, and the Fortunate Islands, to themselves, on Condition of remitting such or such Portion of the Profit into the Cash of the Republic, and of leaving the Commerce of *Bætica* entirely free as before. Ever since this was done, the Inhabitants of the Fortunate Islands, and *Albion*, seeing always the same Company of Merchants equally determined never to go beyond a certain Price in all their Purchases, have considerably abated the Price of their former Sales. The Importations and Exportations are become advantageous again. Our private Merchants no longer sink their own Fortunes in that Branch of Trade, by ill-concerted Enterprizes superior to their Ability: And the Share which the Republick has in the Benefit of that Trade, as well as in the regular Supply of the *Grecian* Troops, who understand War better than we do, engages the Senate to relieve the Company of *Utica* in such Accidents as might shake the Foundation of it; so that the Credit of the Nation is maintained with Honour, both in the Islands, and at *Lacedæmon*.

It is indeed of little Signification to the Republick, whether the Bulk of the Profit of these Undertakings remains

mains in the Hand of *Sichæus*, *Hanno*, and *Adherbal*, rather than in those of the Merchants of *Hadrumetum*, *Clypea*, *Hipponium*. The State has no Preference to make. Every one of its Members are equally dear to it. But it is of Moment to the Republic, that no Body should ruin himself for want of either Substance or Discretion: And if it can reasonably grant Privileges, it must needs be to such Citizens as procure it Riches; because the Riches acquired by the State are afterwards distributed among the Bulk of the Nation, by gradually facilitating the Diminution of the Tax, and the Discharge of private Merchants. 'Tis what the State arrives at in foreign Trade, by the Precaution of exclusive Privileges and Protections. The Treasures of that Company will, in Time, become the Safety of private Traders.

These intermediate and well-tried Ideas cast a Light upon the two others, the Connection of which was not presently perceived; and they shew, that the public Good is inseparable from the special Privilege and Protection granted to a Company of Navigators, to trade among Nations that are very remote, and independent on us.

But, the better to know the Process of the Operations of a reasoning Mind; let us borrow another Instance from two Difficulties started against the Company of *Utica*. The first is, that it is detrimental to the State, because it carries to the Islands nothing but Money instead of our *African* Commodities; the other Objection is, that ever since the Establishment of that Company, for the carrying on of foreign Trade, inward Commerce is not the better for it, and is even more languid than ever.

The Mind needs not, for the clearing of this twofold Difficulty, have Recourse to Categories and syllogistical Rules; to the Discussion of complex or uncomplex Ideas; or to modelled, particular, and universal Propositions. All it has to do, is to borrow from Experience something better known than what is objected, and that may have a Relation to it, in order to answer or remove the Objection.

1. It is a well known Matter of Fact, that exporting Money is no Detriment to a State, when the Species that goes out of it for some Operation in Trade, is sure of coming back with a considerable Interest. 'Tis true, our Company carries a great deal of Money to the Fortunate Islands,

Islands, and *Albion*; but all we buy there is infallibly sold again, and with great Profit too, in *Greece*, or at *Tyre*, or somewhere else. The Company brings them back more Money than it carries away; and thus the Objection vanishes.

2. That which is grounded upon the drooping Condition of inward Commerce is much more frivolous. When Children happen to hurt themselves, they vent their Anger upon whatever chances to be in their Way. Our Merchants do very nearly the same. They see the Company of *Utica* prosper before their Eyes, whilst their Trade is almost extinct. They lay it to the Charge of the Company: But if you suppress it, will they sell a great deal more of their Cloth for it? not an Inch.

If they have a Mind to know the true Cause of the Decay of Home-trade, and the only Remedy for it; they need but go back from one experimental Idea to another. Ideas of this Kind are closely connected, and always go Hand in Hand. Home Commerce is but small, because the Consumption of Clothes and Provisions is not great. This Fault, when general, must of course be in the Multitude. The Multitude never cease to consume, but because it ceases to work and receive Salaries. It works not, either because it has no Work to do, or delights in doing none: And it is perhaps for both Reasons at once, that is, because some are not displeased to be the Objects of public Compassion, whilst others who wish to work, have neither the Matter, nor the necessary Advances for it.

The Remedy for this Evil is by no Means the Suppression of the Company: which would rather double the Mischief, on account of the Idleness into which it would plunge that infinite Number of Hands and Matters employed by the Company. The only infallible Means of animating the Consumption, is an universal and constant Attention in the Magistrate, to employ able Men, either in public Works, such as the repairing of High Ways, the draining of Marshes, and great Buildings; or in common Manufactures, and others; even though one should sometimes pay for Works not over necessary. All those who can work, being sure of their Gain, will marry without Fear, furnish their Houses, and regularly consume a Quantity of Stuffs, Leathers, and Provisions. If the Multitude occasions

sons a constant Consumption every where; Farmers, Merchants, Manufacturers, and Landlords, will constantly sell their Crops, Wares, and Commodities of all Kinds. The voluntary Advances, and public Money, employed in procuring at any time Work, and consequently Cloaths and Bread to Families in low Circumstances, would infallibly turn to the Advantage of the most substantial, and render the whole State flourishing and easy. Therefore, *The chief Resource and Spring of the inward Trade, which is the Life as it were of Society, consists in the Vigilance of a Magistrate intent upon procuring Employment to such as sometimes want it, and upon facilitating Consumption by the Certainty of Work.* When the Artisan, who works To-day, knows not what will become of him To-morrow, the very Thought sinks his Courage. He abridges himself of Necessaries, and Despair persuades him at last to become a pernicious Member of the State, by taking to Robbing and Beggary. Such is and ever will be the main Cause of a drooping Trade: Nor can the Magistrate revive it, but by preventing the Idleness of a Multitude of Hands by the Certainty of Employment, and the more his Prudence enables him to obtain this Capital Point, the greater Politician will he be esteemed, and the Object of an eternal and universal Gratitude.

Let us now leave *Carthage*, and borrow from our modern Customs a few more Examples fit to exercise our Reason upon, and to make us perceive its Method of Proceeding.

They make it a Query; whether it is more advantageous to leave the Assessment of the Tallage, or Land-Tax, to the Arbitration of the Collectors, who take that Office by turns in every Place,* and who on account of the Necessity they are under of having a mutual Regard for each other, as well as on account of their being acquainted with their respective Abilities seem to be very fit Persons to make a just Repartition of the said Tax, or to establish a Tallage, and register it in a Book of Rates pro-

* In *France* all the Peasants of a tallageable Country are yearly and successively Collectors of the Tallage, two and two at a time. And the Imposition of that Tax which ought to be proportioned to the Lands they are Tenants or Owners of, is left to the Judgment of the two Collectors for the Time being.

portionable to the Income, Rent, or Profession of every tallageable Man.

Public Good and arbitrary Tallage are the two Ideas to be connected or disjoined. Our comparative intermediate Ideas are these. In the Hypothesis of an arbitrary Assessment of the Land Tax, the most substantial Men always find in their Friendships, as well as in the Notion of the Services they are thought able to do to others, infallible Means of being treated more favourably than the rest, which must needs overcharge or even crush those who have less to depend upon. The Collector is sure of the Hatred of all those who think themselves overcharged, and who is the Man that does not think so? He leaves his Place to another, that takes his Revenge for the Vexation of the foregoing Years: This becomes the Seed of hereditary Enmities still more fatal to the Families than even the new Burden which is the Occasion of it, and even where there is no Spirit of Revenge, as many and as great Evils may often arise from a Meanness of Soul. Nothing so wretched as the Views and Judgments of a Man, without the Advantages of Education to direct him. He sees almost every Thing wrong. A Silver Edging upon the Brim of an Hat, a Coat made of a substantial Cloth, a Bit of Lace that is a little shewy; such are most commonly the Motives of his being persuaded that a laborious Artisan is in good Circumstances, and that he will be able to bear a greater Portion of the Assessment. The most tattered will of Course be used in the gentlest Manner. Hence that Custom, so very common, of burying Money in the Ground, where it lies idle, and is even lost very often by that Means. Hence the Slovenliness, and ill State of Health, and the suppressing of all Decency, in point of Eating, Furniture, and Apparel: Hence the total Destruction of all Hope and Content: Hence the unavoidable Character of Meanness, Timidity, and Disguise, which renders some Countries Scenes of Grief and Misery.

The Idea of arbitrary Tallage is then demonstrated utterly incompatible with that of public Good, by intermediate experimental Ideas, that separate and render them irreconcilable. The Evils resulting from the arbitrary Assessment of that Tax are summed up in these few Words; It destroys Commerce, and perverts the Character of a Nation.

On

On the other Hand, a proportional Tallage, well assessed and managed, remedies a Multitude of Evils, and is liable to no ill Consequence whatsoever. Here the Logic of the Peasant, and that of the Civilian and Tradesman, though attended with Ideas, in Appearance very different, yet, in the exactest Truth, amount to one and the same Judgment; to a Judgment borrowed from Experience, and, on that Account, supported by a threefold Degree of Evidence.

A Countryman, whom I asked one Day, what the People of his Village thought of the Introduction of the proportional Tallage, answered me by a rustic Joke, That he used formerly to smother his Hog between two Mattresses, for Fear of being thought too substantial, and of being assessed higher on that Account, but that he now killed it to the Sound of a Fiddle, without the least ill Consequence.

Ask Lawyers their Opinion of this Establishment; they will begin by building upon the following Principle, which is an intermediate Idea to them, *viz.* That there is no Happiness to be hoped for, where there is not a just and well regulated Liberty; but that this Liberty is never found but under the Government of the Laws. Whence it follows, that the settling of the Tallage being converted into a well known Law, into a public Rule, common to all; every Man knows his Condition, and lives easy, because he has nothing to fear from the Caprice either of the Assessor or Collector.

Nor is the Merchant less ready to acknowledge the good Effects resulting from this Order: All the Wishes of the Merchant are for quick a Consumption of Commodities, which he thinks, at the same Time, productive of public Good; but that the same Consumption is, in his Opinion, and according to Experience, an Effect resulting from Liberty and Security. So long as the tallageable Man is assessed in a known Proportion, he is sure of paying no more than according to what he has. He is not afraid of seeing his Labour punished, nor of being overcharged and miserable, for having been more industrious, or more laborious, than another Man. His *Quota* being once paid, he may, without any uneasiness or Danger, exert his Prudence and Ingenuity. If it is his Interest to look like one in good

Circumstances, in order to promote his Commerce by the Facility which attends Credit, or to marry his Children to Advantage, from the Reputation of their being always well brought up, he will have Wine in his Cellar, rather than buy it for twice as much at the Tavern: he will provide himself and Family with good and substantial Cloaths, rather than with Jackets of Ticking, which are of no Service to him. He will lie upon a Feather-bed, or a Mattress, rather than upon his former Straw-bed. Now, if the Inhabitants of a populous Country use themselves to good Cloaths and Furniture, it presently increases, to an immense Degree, the Sale and Manufacture of Woollen Stuffs. Wool, that precious Commodity, is no longer in any Danger of sinking in its Price, and of being undervalued, from the necessary Consequence of the Reluctance of Country-people to use it, and the Fondness of the Inhabitants of the Towns for more shewry Stuffs. The Sale of Silks, Woollen Stuffs, Drinks, and Victuals of all Kinds, being brisk, and the several Branches of Commerce thriving, the whole Kingdom must be the better for it. Therefore the proportionable Tallage which encourages the Consumption, does, of Course, secure the Tranquillity of the whole State.

This Question once cleared, becomes the intermediate Idea of another Question, *viz.* Whether it is the Taxes that render a Nation miserable? From what has been said, it follows, that it is not so much the Imposition that causes the Evil, as it is the Fear of being over assessed and prosecuted. For the Tax being proportionable to the Ability of every private Man, may, on the one Hand, be as tolerable as it is necessary; and it procures, on the other, that Kind of Circulation which is most useful to the whole State, by the manifold Employment of the Specie. Whereas the Fear of being over-rated and arbitrarily used, exhausts the Courage, the Industry, and the Expence; that is, all the Sources of the Consumption at once.

But, is then the Ease of the People, which proceeds from the Certainty of their Works, and the wise Proportion of the Tax with their Abilities, so strictly connected with the Security of the State and true public Good, as we imagine? This is a Question which two Sorts of Logicians take upon them to discuss. Let us first listen to the Logic of the rich Proprietor,

Proprietor, we shall afterwards come to that of common Sense, to the Logic of Humanity.

The Proprietors of Lands, who most commonly think they are born to possess the Earth exclusive of all others, see at one View; and from a Sagacity peculiar to themselves, that the Indigence of the People encreases the Number of the Hands who are to make their Harvests; and that ploughing and cropping will be cheaper in Proportion as the common People are miserable. Now, these Harvests and Ploughings made at a cheap Rate, and with Mildness and Submission, are the chief Good of the State. Therefore, making the People thoroughly subservient, is what maintains every Thing in Order, and secures true Subordination.

My Intention was, next to this, to listen to the Logic of Humanity; but, it would have too many Things to say to us here, and we shall be contented with referring the Rich to the Ideas resulting from Experience, and connected with their true Interest.

You wish to be happy, we might say to them, and you destroy your own Happiness by your Way of arguing. Can you call that a Happiness which you are never sure of? And how will you be certain of your Condition, if you strike at the Foundations of it yourselves.

You preach up every where the Maxim of keeping the People in Want, in order to render them submissive, tractable, and pliant. I grant, if you will, that the Multiplication of wretched People, procures you Plenty of Workmen that give their Labour for a small Salary. They will live as long as this Salary lasts: But you know what the Condition of these poor Individuals will be, when there is no more Work for them to do. Would it not be much better for yourselves to give them greater Wages, and act in concert with the other Proprietors, towards procuring all the Labourers of the Places where your Estates lie, an uninterrupted Continuation of Employments, rather than be exposed to their Insults, or be for ever giving Alms to Legions of starving Wretches, or under the frequent Necessity of remedying the overflowing Evil, by involuntary, and most commonly insufficient Contributions?

Labourers are the Majority in a State: If they are not happy, you must not entertain the least Thought of being

so yourself. Their Ease is the only Thing that can increase the Number of tallageable People; that can prevent Deficiencies in the gathering of Taxes, and of Course prevent new assessments, which are a necessary Cause of the others being crushed: Nothing but their Ease can occasion a Multitude of small Expences, which are repeated daily and every where, and on which a brisk Consumption of Commodities, and the Spring itself of Commerce depend. Consequently, it is that, and that alone, which maintains the easy Sale of your Farmer's Crops, which keeps up your Leases upon a constant Footing, and ensures your Rent. Your Maxim, on the contrary, by keeping the Low in endless Misery, ruins the Labourer, the Farmer, and the Merchant; it strikes at and shakes the public Stocks, and consequently the whole State. These are the intermediate Ideas, which being placed between those of public Security, and public Misery, render them altogether irreconcileable.

Thus, by every Method Reasoning imaginable, we cast a Light upon the dark Relation which is between two Ideas, by the successive Application we make of it to other Ideas, whose Certainty is grounded upon Experience. But, although this Method of investigating Truth is natural to every Genius; here are, nevertheless, a few common Precautions, which are not always thought of, and the overlooking of which may throw us into Mistakes.

The Definition and Unity of the Sense of the intermediate Idea.

These intermediate Ideas, which are thus applied by Turns, to both Extremes, must, in the Application, which is successively made of them to two other Terms, be understood in the same Manner on both Sides: Or else, they would no longer be a common Measure. It is then absolutely necessary, truly to fix the Sense of the intermediate Idea, and to remove whatever double Meaning and Obscurity there may be in it. This is obtained by an exact Definition, that clears and settles the Signification of every Word. It was for Want of such an Insight as this, that *Ebbon*, Archbishop of *Rheims*, deceived himself and others, when he argued thus.

The Man who is cut off from Society, has lost all the Prerogatives of it: He loses his Estates, his Vassals, his Crown, and all his Rights whatsoever. Now, *Lewis the Debonair*

Debonair is cut off from Society; therefore he has no longer any Claim to any Thing.

The Society spoken of in the first Proposition, is Society in general; whereas, the Society meant afterwards, is confined to the Ecclesiastical Communion. These two Societies are not then one and the same Measure: Nor is *Lewis the Debonair*, whether we suppose him well or not well, cut off from the Communion, therefore cut off from Society.

Very commonly, the intermediate Idea offers itself to the Mind in the Manner and by way of Condition; so that the Certainty of the principal Object depends, in that Case, on the Certainty of another Object, which must be examined, in order to be certain of it. For Instance: If there is a Justice which rewards Virtue, it is in another, not in this present Life: Now, there is a Justice which rewards Virtue: there will then be another Life after this.

The principal Idea that fills up the Mind in this Place, is the Reality of another Life to come. We see it not; and we endeavour to make ourselves sure of it, from the necessary Connection it has with Divine Justice, of which we cannot doubt.

If we suppose it possible for a Man who reasons, to entertain the least Doubt concerning the Justice that will *in Time reward Virtue*, this Dilemma may be removed by a like Argument, and by Means of a second intermediate Idea that shall be proposed again, by way of Condition, in order to be examined.

There is a Justice, which reserves the Reward of Virtue to herself, if that Being who has conveyed Order into the Nature of Bodies, has established any among intelligent Natures. Now, the Creator, who has conveyed Order into Nature, has established a no inferior Œconomy among Intelligences; since he gave them Knowledge, an Aversion to Injustice, a Value for what is Good, a Conscience, and the Expectation of a better State to come: There will then, soon or late, be a Time for punishing Evil, and rewarding Virtue. The Goodness of these Arguments, consists in being sure of the Reality of the Conditions.

Sometimes the Condition, or any other intermediate Idea, is proposed by way of Division into several Cases, which are the only ones actually in Question, and the only possible ones. The Exactness of these Arguments, depends on that of the Division. For Instance: Here is a Man who retired into a Convent, and has no Taste whatever for Sciences: What but a Sluggard will he be there?

This Reasoning, so very common among Satyrists, is false or uncertain, on account of the Unexactness of the Division. People know but two Kinds of Solitaries in Convents; some who apply themselves to Sciences, and others who pass away their Lives in Idleness. But there is a third Class of them, that can never be valued too much, *viz.* those who consecrate themselves to Prayer and Handy-work; a Kind of Employment, which is the more useful, as Piety is the Rule and only Spring of it.

There is an infinite Number of other Reasonings, of different Form and Character, which may all of them be expressed with Fire, with Energy, and in a very few Words; but scholastic Philosophy affects to protract them, artificially tacking all the Parts of them together, to form a Thread of Syllogisms. Then she methodically goes back, and resumes each Proposition severally, in order to recal the Nature and Properties of them to so many different Rules. The whole may be agreeable to Truth and Reason. The Study of these Rules, and the Application which is made of them to Arguments in Form, may sometimes be attended with the Certainty of Geometrical Demonstrations. But, Life is too short to be employed in idle Speculations. We reason very well, without this long tedious Method. It gives no additional Facility; nay, it even facilitates the Operations of our Mind much less than a quicker and more expeditious Way of reasoning would do. The latter renders the Mind more active and sagacious; the former makes it heavy and absent. Let the following Instance shew you what we get by being too much taken up with the Rules of Art. The Turn of Scholastic Minds, is often like the Gait of certain Dancing-Masters. The wit of these Men lies in their Legs: 'tis plain it resides no where else. A Man liberally educated, steps more nobly than they do, without so much as thinking of it; merely because he is more natural. A Man,

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who would affect to dispose, according to the Rules of the Logick of the School, the Reasonings he should make upon any Topic proposed to him, would likewise resemble a Child, who never speaks *Latin* but with a distinct Attention to such or such a grammatical Rule. A Stiffness of this frigid Kind would infallibly chill the Mind, and lead it into Mistakes, by making it less intent upon the Matter in Hand, than upon the Method of treating it.

Besides, it is a known Matter of Fact, that Eloquence and sweet Persuasion expire on the Lips which never open but with Syllogisms. We know certain Nations whom a frequent Use of the Syllogistical Jargon renders altogether incapable of speaking in the Pulpit, or at the Bar.

The Conclusion and Recapitulation.

It suffices then to the Mind, to fix all its Attention upon its Object, and above all, to contract the Habit of discerning whether what it thinks it perceives is sensibly and strictly connected with comparative Ideas more distinctly known than the Things it endeavours to prove. This last Rule is the Recapitulation of all Logick. It often happens, when we transgress it, that we attempt to prove a Thing real, by another, that has no Relation to, and is no way the Proof of it; or it happens (which is still worse in my Opinion) that we attempt to realize what is not, by Means of Things which are not. A Man has a Mind to shew that the Earth is immoveable, and in the Center of the World *. The intermediate Idea he makes Use of, as being best known, is a Thought he is prepossessed with, *viz.* that the Influences of the Stars and Planets fall on the Earth in a strait Line, and without Interruption: Which would no longer be the Case, if the Earth was carried round the Sun in an Orbit of several Millions of Leagues in Diameter. It is plain, that the Influences would often glance upon, or pass a great Way from it in its Changes of Place, which would disconcert the whole System. But, this is proving a Thing void of Reality, by another equally destitute of it. It is attempting to connect the Steadiness of the Earth, which is contradicted by Experience, with imaginary Influences no less contradicted by it, or destitute of satisfactory Proofs: It is explaining

* The Logick of *P. R.*

what is unknown, by what is unknown; so that the whole remains still in the Dark.

The greatest Part of those, who reason wrong, commit Mistakes upon no other Account, but because they take for subsidiary, clear, and sure Ideas, those which are familiar to them. They fetch their intermediate Ideas from their favourite Tenets and Prejudices, from Self-Love, from the partial Opinion they are prepossessed with in Favour of their Country, Nobility, or Order; very often from previous Engagements, which they no longer distinguish from sound Reason, and oftner still from their Hatred, which poisons every Thing, or their Friendship, which approves of, or excuses every Thing. Sound Logick, in all its Steps from what is more known, to what is less so, scrupulously lays aside all personal Prepossessions, an insinuative or a magisterial Tone, insnaring rhetorical Figures, Fortune, Hopes, and whatever can embellish, or cast a dazling Light upon a Subject.

Nor is it less faithful in discerning and honouring Truth, although it should have very uninviting Outsides, and notwithstanding its being neither commodious nor profitable, but rather attended with low and vulgar Ways and Manners. Sound Logick is, above all Things, careful not to commit any Mistakes, as to what thwarts its Purposes; and the first Thing it does, in Point of personal Affairs of all Kinds, is, to consider earnestly whatever favours the Sentiment of others; and, if possible, to help them to be in the Right. Thus it divests Truth of every Thing foreign to it, and of what cannot be alledged in Favour of, or against it.

The Method made use of to arrive at Truth, is not the same with the Manner of proposing it to others when found. In all our Researches, we naturally, and without Rule, or from meer Necessity, begin by considering what has a sensible Connection with our actual Wants, and then we pass on to the Things that have a less direct, less evident Relation to them. We amass and bring them together; and we reject what is unconnected with, or useless to our present Purpose. We collect the Things which may be sorted, and of mutual Support to each other; and finally, we make of them a total Sum resulting from their Agreement and Union. Thus Historians connect Monuments dispersed here and there, to compose their Histories of, whilst the

Architect

Architect amasses scattered Materials to construct his intended Fabrick. In our Law-Suits and Discussions, and in all the Enquiries the Human Mind is capable of forming, we begin by particular and experimental Truths: We make sure of one Thing, and then of another connected with it. We do not sometimes perceive the Relation which two or three Objects bear to each other: Nevertheless, we study them separately, because they prove to have a Connection to some fourth Object we are chiefly employed on. The Mind, by considering them in many different Lights, at last perceives what it is they agree in, and by that Means it becomes able to make up with them a Demonstration, every Part of which assists and corroborates the Whole. This is what they call Analysis, or Method of Resolution.

The two opposite Methods called Analysis and Synthesis.

But when we are to shew others a Series of Truths, which we have convinced ourselves of, we no longer go about it with the Detail of particular Enquiries. We begin by establishing general, plain, and universally acknowledged Truths, which containing the particular Species, easily lead the Mind from what it knows, in a general Manner, to the Application of it to such and such peculiar, or less well known Objects or Truths, of which it had not a sufficiently just Idea, or compleat Conviction. This is the Method called Synthesis, or Method of Composition; a new Field for multiplying Precepts and Rules. But, whether we meditate for our own Instruction, or discourse for that of others, the great Art of Reasoning and ordering our Thoughts, is no more than the Exercise itself of our reasoning Faculty upon experimental Things, and the Habit of employing what we are already convinced of, to arrive at the Demonstration of what has a certain Relation to it.

If so it be, the practical Sciences, which we are now going to enter upon, are a true and perpetual logical Exercise, since they only turn upon what is Experimental, and the Mind cannot see its Reasonings rewarded by Effects which justify them, without acquiring thereby a greater Degree of Rectitude and Facility.

Of Universal Science.

DIALOGUE XIII.

THE Univerſal Logick we have juſt treated of, is not, properly ſpeaking, a Science which a few Men teach, or acquire apart, and by themſelves, and unknown to the reſt of Mankind. It is nothing more than Reaſon itſelf; it is merely common Senſe more or leſs unfolded and exerted. Nor is this unfolding of Reaſon the Reſult merely of a few abſtruſe Meditations, upon the Proceedure of the human Mind, nor the Effect of a Set of general Rules ſcientifically connected in a Book. The reading of ſuch Rules, may, as well as that of any other Treatiſe that has Truth for its Baſis, be of ſome Utility; but Reaſon may with that Help ſtill remain very raw, and in a very ſtaggering Condition. If ſhe has a Mind to contract an habitual Exactneſs, a proper Aſſurance, and ſome Degree of Extent, ſhe will obtain it by acquiring general Knowledge, and by a long Habit of clearly diſcerning the Connection between what ſhe has, and what ſhe has not a diſtinct Knowledge of. She will improve herſelf by taking exact Notice of all the Miſtakes of others, and her own; by inviolably adhering to experimental Truths; in ſhort, by a conſtant Practice of Reaſoning, rather than by the Study itſelf of our reaſoning Faculty, and the Operations of the human Underſtanding; ſuch was the Logick of all Ages. What can then the Science, which Man may acquire and exerciſe his Reaſon upon, conſiſt in? What, above all, are thoſe Branches of Knowledge, which his Reaſon may enable him to practiſe and apply to the Relief of all his Wants?

Now is the Time, my dear Friend, to inſiſt upon the Principle reſulting from our foregoing Obſervations, and which I have gradually inſinuated to you, as our growing Experience intitled me to do it. God, who created all Intel-

Intelligences and Bodies, of Course knows the Nature of them: But Man, to whom he did not grant the Privilege of creating Beings, knows the Bottom of nothing. It will then be the greatest Act of Prudence in Man, to divert all his Thoughts from what God conceals from him, and never to be taken up with any Thing but what God has placed within the Reach of his Eyes and Hands, in order to exercise his Faculties.

Let us chuse but one single Point in this whole Universe. If Man will discourse upon that Point, upon that first Beginning of a Line, or of a Body; he may do it as a Geometrician, or as a Philosopher. If he speaks of it as a Geometer, as a Husbandman, and in order to measure the Length of his Lands, he, in that Case, conceives the Point as the Beginning or End of a measurable Space; and what he says of it is judicious, because he now keeps within the Limits of his Vocation and Knowledge. Has he a mind to give a philosophical Definition of that Point? He then no longer knows what he says of it: he knows not what a Point is in Nature. All the Definitions of it lead him often to Absurdities and always to something incomprehensible. A Point, you are already sufficiently convinced, a single Point is enough to put all the Schools in the World in a Combustion.

But what Need has Man to know that Point, since the Creation of such a small Being is beyond his Power? *A fortiori*, Philosophy acts against all Probability, when, from that Point which absorbs and disconcerts all her Meditations, she presumes to pass on to the Generation of the World, or the ordering of God's Decrees; when notwithstanding her being intimately conscious of her own Incapacity, concerning the Structure of individual Beings, she takes upon her to reduce the Composition of the Universe into an intelligible System, or of her own Authority, to force a Religion upon us.

There is certainly a sound Philosophy, but what is it? True Philosophy consists, very propably, in admitting of Religion, since God has revealed it by Facts, and in making a proper Use of this World, which God has not commissioned Philosophy to construct.

As for the rest, let human Wisdom carry its Conjectures as far as she pleases, and talk as loud as she will of her Prerogatives: let her mistake at her Pleasure the Facility

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she has to start Questions, and create Difficulties, for a Source of Knowledge and Penetration: Let her fancy herself intitled to judge of Natures, because she can judge of Numbers and Proportions; we are not against any of these fine Things, and will not contest any of her Pretensions: But, as we are sensible of the Danger of hunting after Sciences most probably refused to us, we eagerly lay hold of that Kind of Knowledge, that may be satisfactory to a rational Mind, and render Man both better and happier.

Man is appointed either to govern Minds, or to convey Order among the Bodies that surround him. Nothing more simple and more fruitful at the same Time, than the Kind of Knowledge with which God has endowed him, towards facilitating this twofold Government. *Facts* and *Measures* are the Subjects, which the Exercise of his Reason, and his usual Science is chiefly to run upon.

We have nothing more precious upon Earth than Religion; next to which our greatest Treasure is Juris-prudence, which rules whole Nations, and private Men; then Physick, Œconomicks, Polity, Policy, Agriculture, Trades, Arts, and Commerce, which are the Supports of Life. Man has no true Prudence, nor any solid Comfort in all his Concerns, no more than in all the Operations of his manifold Governments, but in Proportion as he is guided by the Certainty of the Facts, and by the Judiciousness of his Measures.

FACTS.

Religion. WE need not, in order to inform Man of his Origin, Obligations, and Hopes, propose to him any intricate Disputes, or profound Meditations: This is the Method of Philosophers. Alas! how many have stiled themselves Divines, who were no more than such Philosophers. God leads Man quite another Course. The Knowledge of a small Number of Facts, is sufficient to let him into the right Way of Salvation: These Facts manifest God, and his divine Will to him; he finds therein the Objects of his Belief, the Rules of his Conduct, and the Motives to every Virtue.

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'Tis true, these Facts are recorded and invariably related in Books that can never be too much cherished and reverenced. But Books are not the only Means by which these truths are conveyed to us; God, unwilling that these Facts, written as they were, should be disregarded or suspected, has dispersed Footsteps and Attestations of them every where. The Deluge, the Promises made to *Abraham*, and the Resurrection of one of his Descendants, are the three principal Facts mentioned in Revelation. The Monuments of all three actually cover the Earth: I hope I shall one Day point them out to you, and I would fain inspire you now with a Desire of investigating them yourself, by way of Anticipation.

But, we have something here still more easy, and better proportioned to the Capacity of the Generality of Men, than the Scripture and the Inspection of Testimonies. The Vouchers of our Estates are deposited in the Hands of public Men, authorized from Age to Age to hand down to us the Facts whereby we are informed of our several Rights, together with the inviolable Acts by which they are insured to us. But, there is no Part of the World where the Notaries, or other public Keepers of our common Archives, come purposely to meet and acquaint us with our Prerogatives: whereas those who are Trustees with the Deeds concerning our Salvation, are commissioned to come to and warn us of the same; so that they are Ambassadors as well as Depositories, which is a double Help to our Reason. When a Relation has bequeathed us the Property of any Thing, we cannot be informed of it in our own Reason, by dint of Meditation; but our Reason leads us to the Notary Public. If God has made a Revelation, and Promises in our Favour; if he has given us a Maker of our Salvation and an Inheritance, our Reason does not tell it us, so as to fix our Notions concerning these Blessings; but she may consult those who keep the Depositum, and is, moreover, forewarned and sollicited not to remain unconcerned in that Respect. Her Prudence does not then consist in considering, by Means of her own Conjectures, whether God has manifested himself to Mankind, and in what Manner he must have done it; but in asking the following Questions. Is there any such Thing as a public Depositum, wherein the Vouchers of that great Event are

are preserved; and do those, who from Age to Age pretend to be intitled to inform us of it, alledge Facts ascertained by Testimonies? Are both the Depositum and the Depositories well attested? The whole amounts to this Point; Reason leads us to it naturally; and she is informed of it by a Crowd of sensible and ever-subsisting Evidences.

Thus does Grace, which makes the *Christian*, lead him by Reason; and it is the highest Degree of Unreasonableness to listen to Philosophers, who, by mere Methods of arguing, and in Prejudice of Facts, attempt and pretend to wrest our Vouchers and Hopes from us, or to reform the Depositum, by introducing into it Things hatched in their own Brains. Reason has no Power against Archives; and the Employment of a Means of Salvation, so proportionable to our Wants, is a Conduct no less full of Goodness towards Mankind, than of Prudence and Wisdom. The Depositum settles us all: The Ignorant, the Wise, and the very Depositories themselves are subject to it.

Reason is then infinitely commendable, when it does not look out for any other Guide to Salvation than that which was given us, and will not argue upon the Grounds of Religion, because Religion is a Thing already made and settled; and the Authenticity of the Work of God, suffices for Man to regulate his whole Conduct by. There is, likewise, much Judgment in discarding the vain Systems of Philosophy in all the Affairs we are to manage, and in all the Operations we are to direct. Reason is contented, in those Cases, with a Number of well supported Matters of Fact, which become her Models or Principles of Conduct, of which she daily learns how to make a wise Application. What are Œconomics, Physics, Juris-prudence, Commerce, Politics, Polity, and all other Branches of usual Knowledge, but a Heap of the most certain Facts Men have been able to collect upon every Subject, from which Reason draws such Consequences as may both direct her new Trials, and guide her in her ordinary Operations? Such is our Condition, which puts all Genius's upon a kind of Level, by humbling the most extensive, from a Sense of their limited Capacity; and encouraging the weakest, from the Consideration of the Facility with which they may be assisted by the

The Human Sciences, Oeconomicks, Physicks, Jurisprudence, &c.

the Knowledge of others, and from Day to Day add new *Instructions* to those they have already received.

The two noblest Sources of Instruction, and those which contribute most to the Acquisition of the Sciences I have just mentioned, are the Study of Nature, and the History of Mankind. They might be stiled the first Magazines of sound Philosophy. I shall say but a Word of one and the other.

We have very great Obligations to those who have digested and put Sciences in good Order, and taught them methodically by the Synthesis. But this is far from being always the most agreeable Method; and the History of Nature, which exposes analytically, and in a particular Manner, the Facts that may serve as Foundations to most of the finest Sciences, is infinitely more engaging than the Generality of a System which begins with embracing the Whole of a great Subject at once. It does, in some Sense, for every private Man, what God has done for all Mankind. Instead of shewing Things to Man in a general Prospect, God has presented them to him by Parts, at Distances, in different Places, and at different Times. He let him collect the several Pieces of his Knowledge, and assigned him the Honour of connecting the Whole. Natural History, likewise, offers us, in every kind, a Number of Facts, which engage us much by the Charms of Novelty. It gradually ripens our Reason by the Judgments she passes upon it, and renders the Mind inquisitive, and fond of making Observations, Trials, and Discoveries. It is then because Natural History unites in this Manner both the Charms and the Benefit of Experience, that she is, for Beginners especially, the most natural, as well as the surest Method they can possibly follow. They will at least speak of Things they have seen.

The Excellence of the History of Nature.

It is the same with Civil History, which is properly the History of the human Mind, the Science of the Heart, and the School of Society. There are many People of Merit, who set a greater Value upon a good Maxim, or a judicious Saying, than upon a Series of Facts; and who will, at any Time, rather chuse to put into the Hands of Youth Collections of Morals, than historical Facts. Their Intention

The Usefulness of Civil History.

Intention in this, is to form the Judgment by the Truths resulting from Actions, rather than fill up young Minds with Battles, or other Events, that seem not fit to convey any Instruction: But, be pleased to put the *Adages* of *Erasmus* in Opposition to the History of *Alexander*, or of the Viscount *Turenne*: *Erasmus*, with his heavy Quintessence of Rules, Maxims, and moral Reflections, shall have no Body on his Side: they either will not peruse him at all, or they will yawn at reading him. Whatever new Moralities People have attempted to add to the few Reflections of the Duke *de la Rochefoucault*, where very ill received by the Publick. His little Book was fully sufficient for the thinking Age, and will always be too much for one Age which never thinks at all. Nor is it enough, indeed, when you desire to improve Minds, and render them fruitful, that the Things you propose to them be good in themselves; they ought chiefly to be level to, and fit to make an Impression upon Men of the narrowest Capacity. Now, this is the peculiar Prerogative of History: It inchants the Reader, by offering to his Reflections a Chain of Facts, which, although they have not the Air of Lessons, yet are the Seeds of the best Precepts, and, in Reality, contain all the moral Truths which the Mind does herself extract from them in a much more beneficial Manner. I own, that a single Word of Monsieur *de Turenne*, is, sometimes, more affecting and instructive than the Recital of his Battles. But the Merit of that Word, the value of the noble Sentiment it expresses, is never felt compleatly, without the Help of the Fact that occasioned it. You may not only admire the Calmness of Mind, and good Order, that reign in all his Battles, but reap much Benefit likewise, from the Cautions that precede each glorious Day, and the Utility he derives from them. Great Benefit may be reaped also from the very Confessions he makes of his Mistakes. History, in short, never ceases to give useful Instructions, although it never appears so to do. Infinite Wisdom itself used the same Method, when it came to instruct the Man it had created. Instead of always employing plain Maxims, or cold Generalities; it delights in making him discover the wholesome Truth in a Recital, and in the Appearance of a Matter of Fact. Sometimes it is a Sower, who throws his Corn into Grounds differently prepared;

prepared; sometimes the Father of a Family, who sends into his Vineyard the Labourers he finds upon the Place, at several Hours of the Day. It is a Child reclaimed from the Errors of his long Misconduct: Or any other the like Event, intelligible to Men of all Capacities, and fit to invite them to unriddle the Truth wrapt in it. The divine Wisdom knew her Work, and has taught Man according to his natural Dispositions.

The Science of Signs and Words.

The same Practice proves of equal Use in the Study of the Signs or Words whereby we acquire a Means of mutually understanding one another, and of making Use of the Knowledge of those who lived before us. Languages may be studied two different Ways, *viz.* by the agreeable and constant Habit of conversing with those who speak well, and with the politest Writers; or by a long Study of all the general Rules to which Grammarians have taken Care to refer the Structure of the several Parts of Speech, and all the Accidents, Turns, uncommon Expressions, and Changes they are liable to. This Matter is of the greatest Moment, as it is the Avenue to all Sciences. I shall soon treat of it, when we come to the Article of Education; and I hope that, after having convinced you of the Judiciousness now reigning in the present Establishment of publick Studies, I shall make you sensible of the Reason why a much greater Benefit is not reaped from them. This transitory View of the Subjects shews you, how surely and agreeable Facts will contribute to our Instruction, if we are but guided by that sound Logick, or rather sound Judgment, that knows how to make both a proper Choice and Application of them.

The other Part of the universal Science, is the Knowledge of Proportions and Measures.

The Science of Proportions and Measures.

IF Man is a lively Picture of the supreme Master of the Universe, by the Notice he takes of every Thing in his Habitation; he is still more so by the Skill with which he measures the Quantity, Extent, and Forces of the Bodies he employs. He makes himself sure of the Number he shall

ſhall want; he fixes their ſeveral Lengths, and other Dimenſions and Proportions. He meaſures their reſpective Weights and Actions in a Balance, in order to regulate all their Services. Here, more than any where elſe, we find him a Maſter who diſcerns the Value, and appropriates to himſelf the Uſe of whatever he meets with upon the Eſtate he is Poſſeſſor and Owner of.

'Tis true, the Man who is a great Arithmetician, will not, perhaps, be a Geometrician, and the Perſon who is beſt acquainted with the Proportions of Lines and Figures, may be no Mechaniſt. But you will ſee, when we come to the Society of Man with his Fellow-Creatures, how advantageous this Diviſion of Talents is, and in what Manner the peculiar Science of every private Man becomes a general Good to the whole Species.

However, the firſt Ground of all theſe Talents does moſt truly reſide in every one of us. When we attempt to become ſyſtematical Philoſophers, and Searchers of Nature, we bring forth nothing but Darkneſs and Difficulties: But we are all born Mechanicks and Geometers. Now, what we all of us are, without Exception, is very fit to point out to us the Kind of Learning we are appointed to profeſs. One ſingle Occaſion, or an urgent Neceſſity, is ſufficient to awaken within, and produce without us, the Principle of Skill and Dexterity, which other Wants kept there aſleep. *Robinſon Cruſoe*, deſtitute of all Help in his forced Solitude, knows neither how to beat Clay into a kind of Mortar, nor how to burn it. He makes a great many vain Trials, to prevent ſometimes the tumbling of the Walls of his Retreat, ſometimes the ſinking of the Brink of an earthen Pan, which he would be glad to make round, and harden. He uſes all Sorts of Expedients; and with much Precaution, he at laſt, becomes Potter, Carpenter, and Maſon. A Child who begins to caſt up upon his Fingers, and who is told that he is to have a fine Suit of Cloaths, or a Holy-day thirty Days hence, goes and hides thirty Pebbles in a Corner, and daily takes one away, in order to know how far he is from the Date of what he expects. By this Method, he learns both Addition and Subſtraction at once. A Man grown up, but deprived of the Advantages of a good Education, will, notwithſtanding his being a Stranger to the Science of Multiplication

plication and Division, yet make a right Enumeration of the Things he is concerned in, by representing them to himself by so many small Sticks; either to make a Total of a Sum repeated several Times, or to divide a Sum into many equal or unequal Parts. Necessity does not indeed give him any Instruction in point of Calculation; but it compels him to have Recourse to an Industry he was possessed of without knowing it. We shall see another, whose Meditations lead him so far as to make Rules to himself fit to guide him in other Cases, and who orders in his Mind the Sums he is thinking of, by connecting his too fugitive Ideas, with such manageable Objects as small Stones*, or Bits of Slate, to which he assigns different Names and Values, according to the Manner of placing them. From these *Calculi*, or Counters, some of which are reputed to be so many Tens, others Hundreds and Thousands, is derived the Word *to calculate*.

Counters.

Man facilitates and shortens his arithmetical Operations still more, by replacing the Service of Counters with a few Figures or chalked Letters. Thus did the *Romans* shew one Finger, or chalked the Figure. I, which represents it, which they had a Mind to express Unity. II, III, IIII Fingers drawn near each other, expressed the following Numbers. They depressed the three middle Fingers, and extended the Thumb and little Finger only, to express the Number five; which formed the Figure V. They signified Ten, by putting two V one upon another $\overset{\text{V}}{\Lambda}$, or by writing an X. Then they combined the X, the V, and the I, till they came up to Fifty, or five Tens, which they expressed by laying the Five upon its Side, thus <. This figure assumed the Form of an L in this Posture, and they made the Figure of a Hundred with two L thus put one upon another $\overset{\Gamma}{\text{L}}$, and then rounded into a C. LↃ, was appointed to signify five Hundred, and CLↃ to signify a Thousand. These Figures were afterwards changed, one into D, the other into CIↃ, or into ൬, and then into M.

The Arithmetical Figures.

The *Roman.*

* Calculi.

Most

The numeral Figures of the *Greeks* and the *Hebrews*.

Most Nations have followed the natural Arithmetick of their ten Fingers, and are used, in their Additions, to reckon Tens of Units, with which they make up Tens of Tens, or Hundreds, and then Tens of Hundreds, or Thousands. They have, almost all of them, employed, as the *Greeks* and the *Hebrews* did, the Letters of the Alphabet ranged in Order, which was fixed by Custom, to represent all imaginable Numbers.

But, among them all, none employed a lesser Number of Figures, or have more ingeniously varied the Signification of them, than the *Arabians*. Every Man knows the nine Figures and Cypher they have invented. There is no Number but what can be expressed with this short Apparatus, even without much Accumulation of Characters; because the same nine Figures which have expressed Units in one Column, being transposed from the Right to the Left into the next, stand there for so many Tens of Units; and in the third Column for Tens of Tens, which are Hundreds, and for Tens of Hundreds, that is for Thousands, in the fourth; always becoming, in their passing from one Column into another, of ten times greater Value in one Column, than they were in the foregoing. However, the Proceeding of this Numeration, the Skill of making separate Columns to cast up Sums of different Nature, such as Fathoms, Feet, and Inches; the Precaution of putting a Cypher in the empty Columns, in order to keep up the Value of real Figures; a smooth ready Practice of the four common arithmetical Operations; in short, the Golden Rule, which, by Means of three Numbers known to us, immediately reveals a Fourth, which we could not otherwise have found out, but with Difficulty; all these Things, I say, are so very plain, that they often become the Resource and Talent of the most unthinking Minds. Let a Topick be given to twelve Orators, to discourse upon, the same Matter will be cleared by them, and represented in twelve different Lights. The Ground and Canvass is the Work of none of them, but the Arguments, Sentiments, and Beauties they dress it with out of their own Thoughts, have no Manner of Likeness to each other: These twelve Discourses appear so many separate Creations. Give a Calculation to make to twelve different Arithmeticians;

ticians; all the twelve conclude most simply in one and the same Sum, which is at once a Commendation of their Patience, and of the Rules by which they are directed. These Rules are of such infallible Service, and so easy to be learned, that none but People whose Education has been utterly neglected, or marred, can possibly be ignorant of the Use of them. I shall not then, by any Means, insist longer upon them with you. Let us rather pass on to the noblest Part of the whole Scene of Nature. Let us behold Man studying to render his Abode habitable, and making his Profit of every Thing, by the Practice of Measures and Mechanics.

Here we might be stopt by an Apprehension sufficiently well grounded. Geometry, which measures Extension, and Mechanics, which weigh moving Forces in a Balance, are immense Sciences. They truly become such, by the infinite Number of Uses to which they are applied: Besides, they are considerably clogged with Questions, not otherwise useful, and dictated by mere Curiosity. But, the Elements of them are simple: Nor do I intend even so much as to teach you these Elements. I shall only, for your Sake, single out but a slight Specimen of them. The right Line, the curve Line, the Lever, and the inclined Plane, shall be our only Apparatus, and we shall even be contented with the simplest and less complicated Proportions. If these four Instruments, which one might be apt to despise at first Sight, on account of their insignificant Appearance, have nevertheless been sufficient to lead Man to perfect Inventions and innumerable Operations; the natural Conclusion to be drawn from it, and which is the End I aim at, will be this, *viz.* That when Man exerts his Ingenuity, within the Limits of that Knowledge which assists his Government, and directs the Operations of his Hand, his Efforts are infallibly rewarded by the Acquisition of a satisfactory Knowledge, and often even by unexpected Success.

MEASURES.

THE strict Union which is in us, between the Intelligence and the Senses, authorizes us to help the intellectual Substance with the sensible, and *vice versa.* There-

Therefore the ſame right or circular Line that ſhall have been preſented firſt to the Mind as an intelligible Object, ſhall be entitled to appear again under the viſible Form of a Wooden-Ruler, a Braſs-Circle, or any other like Inſtrument. Truths are ſtill the ſame under either of theſe Forms; and it being juſt and requiſite that they ſhould carry their Demonſtration with them, to make us ſure of the Profit to be derived from them; we ſhall endeavour to render them equally ſtriking to both the Mind and the Senſes. Sure their becoming palpable can be no Detriment to them.

Let People afterwards call them Definitions, Axioms, Corollaries, Lemma's, Practices, or any thing elſe, they are very welcome. Here, the firſt Truths, the firſt Inſtruments, and the firſt Operations ſhall be called plainly, 1, 2, 3, 4, 5, and ſo on, according to the Rank in which every Thing ſhall offer, to be afterwards recalled and quoted as need will require. Our Buſineſs is not here to teach Geometry, but only to ſhew how and to what beneficial Purpoſe Man is become a Geometrician.

The right Line.

1. A Line ſtretched between two Pins, gives us the Idea of a right Line, which, from one Point to another, ſwerves neither to the Right nor Left.

2. The right Line is conſequently the ſhorteſt Way from one Point to another; ſince any other Line begins to lengthen, as ſoon as it makes an Elbow; and the more it does ſo, the longer it will be.

The curve Line.

3. A looſe Chord gives us the Idea of the curve Line, whoſe Curvature increaſes with its Elbows and Windings.

4. Therefore, no more than one right Line can be drawn from one Point to another; whereas an infinite Number of curve Lines may be drawn between them, which vary as much as their reſpective Bendings.

5. A line rubbed with Chalk ſtretched between two fixed Points, then raiſed in the Middle, and let go, marks out a right Line, which was ſufficient at firſt to rough-hew and make ſtrait a wooden Ruler, fit afterwards to direct other Lines of the ſame Nature.

6. The Ruler was rendered perfect, by being applied to a Piece of Ice as ſmooth as level Water; or to a Piece of Marble

Marble that was polished by the uniform Pressure of another Marble.

7. The Ruler applied to two Points is sufficient, together with a Pencil, to draw out the whole Line, since that Ruler represents and helps us to find the shortest Way from one Point to another.

8. The Ruler, when applied every Way to a smooth Surface, serves to shew whether that Surface is a perfect Plain, being itself perfectly even.

The plain Surface.

9. Or whether it is convex by rising.

The convex one.

10. Or concave by sinking.

11. The Point may be considered physically, as the smallest Portion of Matter; in which Sense, a Point is as inconceivable to us as the whole Universe.

12. Or, it may be considered mathematically, as the Beginning or End of Length, and as having the smallest Size that can possibly bring it within the Reach of our Senses.

The Mathematical Point.

13. Taking it in that Sense, a Series of Points is necessary to make a Length.

Length.

14. A Series of strait or curve Lines ranged by the Side of each other make the Surface, which is at the same Time long and broad.

Breadth.

15. Several Surfaces being understood, like so many Leaves laid one upon another, form a Depth, or the solid Body, which has at once, Length, Breadth, and Depth.

Depth or Solidity.

16. When we have a mind to judge of unknown Quantities or Extensions, we compare them to a Measure which is known.

17. The Want of a first Measure that might be added to itself, and repeated several Times, caused Men to have Recourse to divers Extensions, which commonly prove much the same; such as,

Instituted Measures.

18. The Breadth of a Grain of Barley.

The Grain of Barley, or the Line.

19. The Breadth of the Thumb of a full grown Man, or twelve Grains of Barley.

The Inch.

20. The Breadth of his Hand, that is, a Palm, or four Inches.

The Palm, or Span.

The Foot. 21. The Length of his Foot, or twelve Inches.

The Cubit. 22. The Length which extends from his Elbow quite to the End of the longest Finger, or a Foot and a Half.

The Fathom, or six Foot. 23. The Length of his two Arms horizontally stretched out: But, as Nature offered us, in all these Things, none but changeable Measures, which necessarily occasioned Uncertainty and Confusion; People in Authority were forced to settle the Measures in each District, by a Standard, or public Measure.

The Line. 24. The first common Measure, is the Breadth of a Grain of Barley, reduced and fixed to a Standard. This Measure, which varies in Nature, and from one District to another, is at least settled and agreed upon within the Extent of a whole Province. It goes also, but in a new Acceptation, by the Name of Line.

25. Twelves Lines, in this last Sense, (that is, under the Notion of the smallest of our Measures) make the Inch, being placed one at the End of the other along a Ruler.

26. Twelve of these Inches make up the Foot.

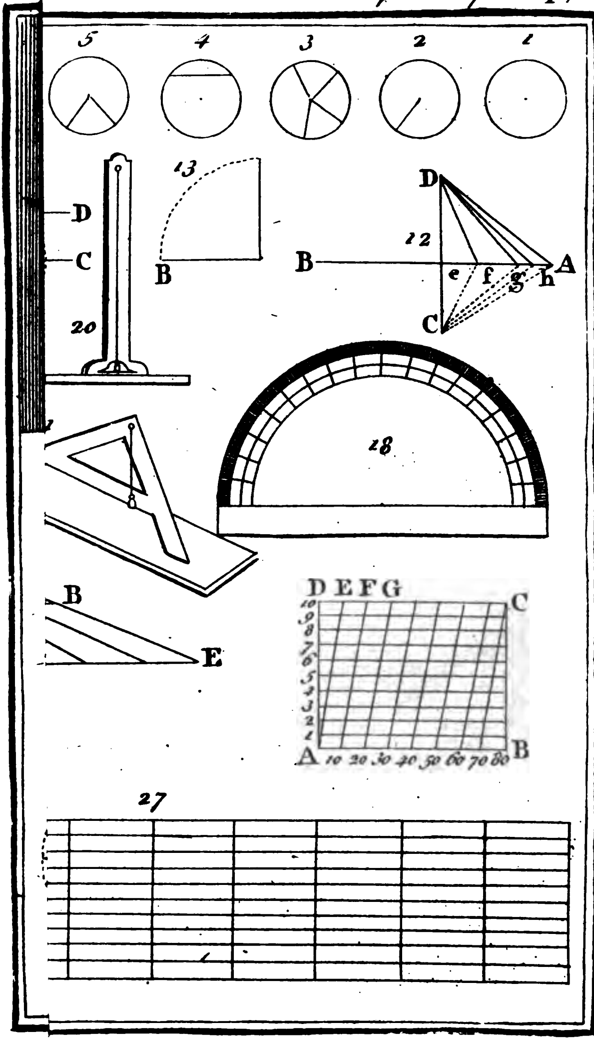
The Fathom. 27. Six Feet make the Fathom.

28. Three Fathoms make the Perch of *Paris*. The Perch is 22, 24, or more Inches in other Places. Two thousand Perches make up our short League: Two thousand, two hundred and eighty-two Perches make our common League; five and twenty of which answer a Degree of the Meridian. We shall pass over the other Measures, the Variety of which is still greater, and even more arbitrary. It is enough, for the Exactness of any Operation, to know what Measure is fixed upon.

Natural Measures. 29. Besides instituted Measures, there are also natural ones, which are the Divisions we make of a Quantity or Extent into two Halves, three Thirds, four Quarters, and so on.

30. You may take upon a Ruler, or any other Extent, whatever Measure you please, by only laying hold of two Points thereon; for (by the second and seventh Propositions) you will always express the shortest Way between two Points, by applying a Ruler and Pencil to them.

31. From


5
4
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D E F G
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10 9 8 7 6 5 4 3 2 1
A
10 20 30 40 50 60 70 80
B
27

31. From the foregoing Proposition, two Rulers wheeling about at one End upon a Nail which unites them, and opening their other two Extremities at Pleasure, are a convenient Instrument to take and keep the Distance of two Points; this is what we call a Pair of Compasses.

The Compasses.

32. The greater or less Perfection of the Compasses consists in the greater or less Uniformity of their playing at the Head, and in the Ending of both Legs more or less exactly in a Point, whereby to take and carry any where else more or less exact Points.

33. All the right Lines of the same Opening of the Compasses are equal, since they are respectively the shortest Way between two Points equally distant.

34. The same Opening of the Compasses is not the common Measure of Curve-Lines, unless you are otherwise certain of their Bending being equal, and perfectly uniform.

35. If you put one of the Legs of the Compasses upon a Point, you may, with the other Leg, draw a Curve-Line, which enters into itself again, and ends where it began. It is called Circular-Line, Circumference of Circle, or plainly Circle. *Fig.* 1.

The circular Line.

36. The Point in the Middle of the Circle is called the Center.

37. The Line drawn from the Center quite to the Circumference, is called the Radius. *Fig.* 2.

38. All the Radii are equal; since they are so many equal Lines of the same Opening of the Compasses. *Fig.* 3.

39. All the Points of the Circumference are equally distant from the Center; since they are the Extremities of Radii, and of the same Opening of the Compasses.

40. The circular Line being as uniform in the Disposition of its Parts, with Regard to the Center, as the right Line is with Regard to both its Extremes; all the Portions of the Circumference, that are taken in by the same Opening of the Compasses, will be equal.

41. The same Opening of the Compasses may serve as a common Measure upon the same Circumference, or upon Circumferences that are equal, but not upon unequal Circumferences: Because,

42. The Bending or Curvature varies in Circumferences, as their Distances do in Regard to the Center.

43. However, as we compare a short right Line with a long one, by dividing the former into as many proportionable Parts as the latter; we likewise find infallible Proportions between a small and a great Circle, by dividing them both into so many proportionable Parts, as Halves, Quarters, Eights, *&c.*

The Arch. 44. One Part of the Circumference is an Arch. *Fig.* 4.

The Chord. 45. The Line drawn and subtended from one End of the Arch to the other, is the Chord of it.

The Segment. 46. A Portion of a Circle, comprehended between an Arch and its Chord, is called a Segment.

The Sector. 47. A Portion of a Circle comprehended between an Arch and two Radii, is called a Sector. *Fig.* 5.

48. The Chord which goes through the Center, is called the Diameter. *Fig.* 6.

The Diameter. 49. The Diameter is double of the Radius, since it consists of two Radii.

50. Any Chord that does not pass through the Center is less than the Diameter: For, if, from the two Points which terminate the Chord a b, or the Chord A B. (*Fig.* 7.) you draw two Lines to the Center, they will be two Radii, which are together equivalent to the Diameter; (from the foregoing.) Now, these two Radii become a curve Line, by making an Elbow at the Center; and a curve Line drawn between the Points A b, or a b, is necessarily longer than the right Line drawn from the same Points (*Prop.* 2.) Therefore the Diameter, which, as well as that curve Line, is equal to two Radii, is longer than the Chord a b, or A B, or any other Chord that does not pass through the Center.

51. The Chord, which does not pass through the Center, cuts the Circle into two Segments, one smaller, the other greater, (*Fig.* 8.) and the largest is that which takes in the Center; since the Diameter which passes through the Center, is greater than that Chord. (From the foregoing.)

52. When

52. When we speak of a Chord and its Arch, we understand the small Segment, unless some Hint be given to the contrary.

53 The Circumference of the Circle may be divided either by a natural or an arbitrary Division.

The Division of the Circle.

54. The first natural Division is made by the Diameter, which cuts the Circle into two Halves perfectly equal: For, if the Circle was of Brass, and the Diameter of it made a turning Joint, by folding one Arch over the other, you would find all their respective Points in an exact Correspondence; otherwise the Points of the one Side of the Circumference would not be, with respect to the Center, at the same Distance as those of the other, which would contradict the Definition of the Circle. (*Prop.* 35.)

By the Diameter.

55. The second natural Division is made by the Radius, the Measure of which, *Fig.* 9. being transferred upon the half Circumference with the Compasses, always cuts it into three, or, when transferred upon the whole Circle, divides it absolutely into six equal Portions, which is an Introduction to a Multitude of other no less certain Divisions, and innumerable Proportions between great and small Figures.

By the Radius.

56. The arbitrary Division is that which divides one of those six Arches at Pleasure. Custom has fixed the Division of an Arch measured by the Radius to sixty equal Parts called Degrees, which are found again in small in the sixth Part of a small Circle, as these sixty Degrees are in great, in the sixth Part of a large one.

The arbitrary Division.

57. This Division is commodious, as it may be subdivided into twice Thirty, thrice Twenty, six times Ten, five times Twelve, twelve times Five, or otherwise.

58. There is the same Conveniency in the whole Circle, which by that Means, consists of 360 equal Parts, divisible into two Semi-circles of 180 Degrees each; into three Thirds of 120; into four Quarters of 90; into eight half Quarters of 45, *&c.*

The Degrees.

59. They also cut each Degree into sixty Minutes, each Minute into sixty Seconds, each Second into sixty Thirds, and so on, if the

The Minutes, Seconds, Thirds, *&c.*

the ſubdivided Parts are of an Extent ſenſible enough to admit of any ulterior Subdiviſions.

60. By Means of theſe Diviſions, and of the Proportions they afford between great and ſmall Objects, we are able to execute exactly in great what we had meaſured in ſmall; and, on the contrary, to reduce the Meaſures of a large Ground into a very ſmall Compaſs, that we may conveniently make there the Diſtribution and Diſpoſal we project for the large Space.

61. We may compare not only a right Line with a right Line, a Circle with a Circle, or one Portion of a Circle with another; but alſo a Circle with a right Line, in ſuch Manner, that the one procures us the Knowledge of the other; becauſe,

62. When you have equal Arches, you have alſo equal Chords in the ſame Circle, for the ſame Opening of the Compaſſes gives equal Portions in the ſame circular Line, and meaſures equal right Lines at one and the ſame Time.

63. Of courſe, and reciprocally, equal Chords ſupport equal Arches in the ſame Circle.

64. If from any two Points like A and B, taken each of them for a Center, you draw two equal Circles, that cut one another; for Inſtance, in C D, *Fig.* 11. the Points of Interſection C D, will be equally diſtant from A and B, and A and B will be reciprocally at equal Diſtances from C D, ſince they are diſtant from each other by a like Opening of the Compaſſes.

65. The two Arches of two equal Circles that cut one another are equal, having the ſame Chord, a common Meaſure C D being taken with the ſame Opening of the Compaſſes upon equal Circles.

66. The Line A B, which unites the Centers of two equal Circles, cuts the two interſected Arches exactly in the Middle. For this Line being ſtrait, and (from 64,) equally diſtant at both its Ends A B from the Interſections C D muſt, in its whole Length, not draw nearer C than D, and conſequently meet the exact Middle of the Arches which have C D for their Meaſure.

67. The ſame Line which cuts the Arch into two Halves, cuts alſo the Chord into two equal Parts.

The Perpendicular.

68. A Line (*Fig.* 11.) falling upon another, without inclining more on one Par than on the other, is called a Perpendicular.

69. The

69. The Line upon which the Perpendicular falls, is reciprocally perpendicular with regard to the other. D C is perpendicular upon A B, and A B upon D C. For, as the Points D C are, from the Construction, distant by an equal Opening of the Compasses from A and B; so are A B distant by an equal Opening of the Compasses from D and C. Now, being certain of two Points of a right Line, is knowing the Direction of the whole Line.

70. To erect the Perpendicular D C on A B, there is no Necessity to draw Circles. It will be enough, if from the Points A B you mark out Portions of Circles that cut one another in D and C. They are equivalent to the whole Circle, because you have, by Means of them, two Points equally distant from A B, (*Prop.* 64.) which (from *Prop.* 2.) is having as much as the whole Line D C.

The oblique Line.

71. From the given Point D without the Line A B, *fig.* 12. but one Perpendicular D C, can be let fall upon that Line. For, all the others that have been drawn from the same Point D, as e, f, g, h, are oblique, that is, inclined, and they are the more inclined to B, as they are nearer to A.

72. Those of the oblique Lines which swerve most from the Perpendicular are the longest; for the oblique Lines h, g, f, e, are the Halves of so many curve Lines which terminate in D C. Now these Curves are by so much the longer, as they swerve most from the shortest D C: Therefore it is the same with their Halves e, f, g, h.

73. This last Method of cutting a right Line with a Perpendicular, serves also to cut into equal Portions a Semicircle, or an Arch, or a Chord, and to find the Center. For, the Line whose Extremities are carried by an equal Opening of the Compasses to an equal Distance of the two Extremities of the Arch, remaining in its whole Length equally distant from both these Extremities, must needs meet the Middle of the Arch, the Middle of the Chord, and the Center; since these three Points are each of them respectively at equal Distances from the Extremities of the Arch.

74. The same Method serves to cut a Circle into four Quarters: For, if each Semi-circle is naturally measured by three Radii, supporting each of them an Arch of 60 Degrees; the Perpendicular which cuts each Semi-circle

exactly in the Middle, leaves on each Side the Value of an Arch of 90 Degrees, equivalent to 60 and 30.

75. Therefore the Circle serves either to find or prove you have found the Perpendicularity of one Line to another.

76. Being required to erect a Perpendicular upon the Extremity A of the given Line A C, *fig.* 13. carry your Compasses opened at Pleasure from the Center A to B, and draw a little more than the quarter art of a Circle; carry the same Opening or Radius from B quite to D; and then cut the Arch B D (Numb. 70) into two, to have the exact Half of your Arch, which Half being carried from D to E, the Point E and the Extremity A of the given Line will procure you the Perpendicular desired. For, three Arches, of 30 Degrees each, are the Measure of the quarter Part of a Circle, since three Arches of 60 measure the Half.

Parallel Lines.

77. If it be required to draw a second Line D D, *fig.* 14. parallel to the first C C, that is, equally distant from it in all its respective Parts; draw a Circle that cuts the first Line in two Points, and from these two Points of Intersection C C take two Arches C D, C D, of the same Opening of the Compasses. From *Prop.* 40. the two Extremities of these Arches are two Points equally distant from the first Line. Therefore the right Line drawn by these Points D D, shall, in its whole Length, keep at an equal Distance from the first Line C C.

Concentric Lines.

78. Circular Lines and Portions of Circle may also be parallel, and will be so by drawing them one under the other from the same Center, *Fig.* 15. For, all the Points of the external Line E are the Extremities of so many equal Radii, and all the Points of the internal I are the Extremities of Radii equally shortened. You have then a Space every where equal between the two. These Circles and Arches are called Concentric, and those which have not the same Center are called Excentric.

79. All the Lines, which terminate at the Center of concentric Circles, make there the same Divisions; of Halves, for Instance, of Quarters, or of as many proportional Degrees as you please.

80. The

80. The Circles within or without each other are still of the same Nature, and divisible into the same Number of Degrees. Therefore the Lines which pass through the Center produce the same Divisions in all Circles. Whence it follows, that;

81. Any small or great Circle is equally fit to demonstrate to you the Exactness of your Measures, by Divisions of 180 Degrees, which are the Half, or of 90, which are the quarter Part, or of 60, which are the sixth, or of 45, which are the eighth Part of the Circle; and so on.

82. When People have a Mind to find these Measures directly, which are indeed of infinite Use, they do not with the Compasses seek for the perpendicular or oblique Lines, and what Degrees they may stand in need of; as these Measures may be supplied with Instruments which contain them before-hand, and will afford as many of them as may be wanted.

83. Although, then, the Ruler and Compasses may procure all; the Square, the Bevel, the Protractor, the Plumb-line, the Level, &c. are added to them for the Sake of Expedition.

The Square.

84. The Square, *Fig.* 16. consists of two immoveable Rules or Branches fastened perpendicularly at one of their Extremes, to direct any perpendicular Line, or divide a Circle into Quarters.

The Bevel.

85. The Bevel, *Fig.* 17. is a kind of Square, consisting of two Rules fastened at one of their Extremes, but moveable on a Joint, to give immediately any oblique Line, or a Perpendicular, according to the greater or less Opening of them.

The Protractor.

86. The Opening of the Rules of the Bevel, and the diverging of any Line from another, is measured with the Protractor, which consists of a Semicircular Limb of Brass, divided into 180 Degrees, *Fig.* 18. The *French* call it *Rapporteur*, because you take upon it the Number of Degrees you want, to transfer and lay them down on the Spot, or on Paper; giving the Lines drawn from the Center the same Divergency they have in the Instrument, the Division produced by the Lines converging and meeting at the Center being the same in the smallest as in the largest Circles.

87. These Operations and Instruments will help you to draw with Exactness a Perpendicular, or an oblique Line raised so many Degrees above the Diameter, when you work on the Ground, or on Paper: but they will not give you a Perpendicular to the Horizon; as for Instance, a Stake planted upright. For this last Operation, they have Recourse to the Plumb-line, which consists of a Thread or Chord, hung to a Piece of Lead, *Fig.* 19. Man knows not the Cause of the direct Gravitation of a Weight towards the Horizon; but he is certain of the Fact, and he makes use of that Certainty to compare the Direction of an upright Stake or Wall with that of a Chord, which the Weight hanging on, retains at the Distance of 90 Degrees from the Horizon every Way.

The Level.

88. When a Line or Surface parallel to the Horizon is wanted, they make Use of the Level, *Fig.* 20. and 21, which is a Rule having a Bar vertically raised on it, and traversed in its Length by a perpendicular Cavity, that serves to admit a Thread fastened at Top of it, to the other Extremity of which hangs a Piece of Lead playing in a small Vacancy at the Bottom of the vertical Bar. It follows from this Disposition, that the inferior Rule represents the Horizon, and is parallel to it, when the Chord or Thread happens to be upon that Rule as it is on the Horizon, that is, without inclining to either Side. Now, this must happen whenever the Chord plays in the fiducial Line or Cavity which admits it: nor does it indeed leave that Line, but when the Ruler drawing nearer one Side of the Horizon than the other, obliges the Chord to incline.

89. A Line falling on another Line, makes an Angle with it.

The Angles.

90. The Point in which the Sides or Legs of an Angle unite, is called the Vertex of the Angle.

The Quantity of Angles.

91. The Quantity of one Angle compared with another, does not consist in the Length of its Legs, but in the Number of Degrees which may be reckoned from one Leg to the other, supposing the vertical Point to be the Center of a Circle, or placed in the Center of a Protractor.

92. An Angle may be of three kinds, *viz.* right, obtuse, and acute.

It

It is called Right, when it takes in 90 Degrees. The Right Angle.

It is Obtuse, when it takes in above ninety Degrees. The Obtuse.

It is Acute, when it takes in less than Ninety. The Acute.

93. The right Line which falls perpendicularly on another right Line, *Fig.* 22. forms two right Angles, of 90 Degrees each, being 180 together.

94. The acute Angle, and the obtuse made by a right Line, *Fig.* 23. falling obliquely on another right Line, are together equivalent to two right Angles; since they fill up the Place of them. If the acute Angle is 45 Degrees, the Obtuse will be 135, being together 180 Degrees.

95. From *Prop.* 93. the Perpendicular being continued beyond the Diameter, or beyond any other Line, without any Regard to the Circle, forms four right Angles at the Point of Intersection, *Fig.* 22.

96. From *Prop.* 94. Any right Line that cuts obliquely another right Line, *Fig.* 23. forms two acute, and two obtuse Angles, equivalent to four right ones, of which they fill the Place, each obtuse Angle having so much more as each acute has less. Therefore,

97. All Angles vertically opposite are equal, the right to the right, the obtuse to the obtuse, and the acute to the acute.

98. A Line perpendicular to another, falls according to the same Direction, and has the same Effects on the Line parallel to it, *Fig.* 24. not inclining more to the one than to the other. Therefore (from *Prop.* 95.)

99. A Line perpendicular to two parallel ones, makes eight right Angles with them, *viz.* four external, without the Lines A, B, C, D, and four internal within the Lines a, b, c, d.

100. A Line falling obliquely on another Line, *Fig.* 25. falls with the same Obliquity on its Parallel, and produces the same Effect with it. Therefore (from *Prop.* 96.)

101. A Line which cuts two Parallels obliquely, makes with them four acute Angles, equal among themselves C b, c B, and four equal obtuse ones, A d, a D.

102. The four external Angles, A, B, C, D, being two acute, and two obtuse, are equal to the four internal ones

a, b, c, d, which are also two acute, and two obtuse. Therefore,

103. The internal alternate Angles, like c b or a d, which are taken on one Side of the Oblique upon a Parallel, and on the other Side of the same Oblique upon the other Parallel are equal, and the same as those vertically opposite. Whence it follows, that,

104. Two Angles on the same Sides of the Oblique within as b d, or a c, and without as B D, or A C, being always one obtuse, the other acute, are equivalent to two right ones. These two last Propositions are of infinite Use in all the Parts of Mathematics.

105. Nothing being more critically exact and necessary, than a true measuring of Angles, the Facility of taking them by Means of a solid Line turning freely at the Center of the Circle, gave Birth to the Invention of the Graphometer, or Semicircle.

The Graphometer.

* 106. The Graphometer is a Silver or Brass Circle, or Semicircle, exactly divided, and having an Alhidade or Rule turning on the Center. This Instrument has been improved with the fiducial Line, (*linea fiduciæ*) the Sights, and the Ball and Socket.

The fiducial Line.

107. The Line, which traverses the whole Alhidade exactly in the Middle cutting the Center, is called the fiducial Line, because it shews, with a certain Exactness, the Degree or Minute you want.

108. The Sights are two thin Plates of Brass, perpendicularly raised on the two Extremes of the Alhidade or Index, with a Slit or Aperture along their Middle, and perpendicular to the fiducial Line, that nothing but the Object required may be seen through both Apertures; which serves to shew, by the corresponding Degree, how many Degrees the Angle between this Object and another, towards which the End of the Diameter has been previously directed and fixed, contains. You may also, for the Sake of a greater Exactness, raise Sights at the Extremes of the Diameter. You may, if you will, instead of Sights, use a Couple of Spying-Glasses, one immoveable, and laid along the Diameter; the other moveable, and shewing upon the Divisions of the Graphometer the Divergency of the

the Angle between the two Objects in Question. A Silk-Thread crossing the common Focus of the two Glasses where the Image is formed, cuts also the Object, and brings the exact Middle of it upon what Degree, Minute, &c. you please.

109. The Ball and Socket consists of a Brass Sphere, or Button, fastened under the Instrument, and two Brass Concaves, which grasp the Button in such a Manner, that by Means of a Screw which fastens the two Concaves at Pleasure, and of a Side-hole, wherein the Neck of the Button may be laid sideways, you are able to place the Semicircle, either horizontally, to take the Angles between Objects on the Earth, or vertically, to take Angles between the Horizon and a Star, or between one Star and another. The Ball and Socket.

110. The last Instrument added to the foregoing, is the Scale, or the Rule divided into Ten, a Hundred, a Thousand, or ten Thousand equal Parts, pointing out exactly the largest Measures, to which these small ones bear a known Proportion. The Scale.

111. You may draw a Scale, by dividing the Side of such a Rule as A B into a Number of equal Parts, that may be to that known Line A B what Fathoms or Perches are to a certain known Extent of Ground; subdividing every one of these Parts into as many lesser as you please, of six for one, for Instance, being thus to each primary Part, what Feet are to Fathoms.

112 You may make a still greater Reduction in the small Scale, by dividing it into equal Spaces, that shall be Tens; such as, 10, 20, 30, 40, 50, 60, 70, 80: and then subdividing each Part into Ten, that will be the Subdivision of the Spaces, 10 and 20, 20 and 30. &c. *Fig.* 27.

113. To have the Division of the Scale, divide the Line, which is the Side of it, into Eight, for Instance; which is a very speedy Operation. Let the Line A B, *Fig.* 27. be the desired Line, or the Line equal to the Side of the Scale you intend. By *Prop.* 77, draw the Parallel indefinite D E: Erect on D E, by *Prop.* 76, and draw through the Extremity A, the indefinite A C, whether it be perpendicular or not, is no Matter; as it will be of equal Service to you in both Cases: However, I shall here suppose it to be perpendicular, The Division of the Scale.

pendicular, that the Effect of it may be easier perceived. Measure upon D E eight Times, the same Opening of the Compasses; from the last Division in D E, draw another Line passing through B, it will come to C. From the Point C draw as many Lines as there are Divisions in D E; they will cut the given Line A B in eight Points, whereby you will find it divided into eight equal Portions. For, although all these Lines must, on Account of their being remoter from the Perpendicular in D E than in A B, of course become longer, and be separated by greater Spaces in D E than in A B; yet they produce in A B proportionable, though smaller Divisions, which have the same Equality among themselves as the great: Since all these Lines which cross two Parallels, and fall on them with the same Inclinations, must of course keep the same Order in small upon the one, as they keep in great upon the other, setting out from the same Point: Now the Divisions in great are equal among themselves; therefore they are also equal in small.

The Subdivision of the Scale.

Having divided your Line A B into eight Parts, being each of them ten Fathom, or Perches; it will be an easy Matter for you to take round Numbers upon it, such as, 10, 30, 50, &c. But if you would fix upon it a Value of 15, 27, 63, or any other Quantity; you must finish your Scale, by a Sub-division, of Ten of each of your eight Tens. To avoid Confusion in such small Space they have found Means to mark all the Numerations in a very distinct Manner, by taking them upon the Breadth of the Rule, in the following Manner.

Upon A B (Sequel of *Fig.* 27.) erect the Perpendiculars, A D, B C, and cut them by ten Parallels equally distant from each other. Then divide the tenth Line D C into eight equal Parts, like those of the corresponding Line A B, and instead of uniting the Divisions by Parallels, draw the transverse or diagonal Lines A E, 10 F, 20 G, and so on.

The Use of the Scale.

114. The Use of all these Measures is convenient. If you have a Mind to take in small upon your Scale the Value of 23 Fathoms: Look out in your Scale for the Meeting of the transverse Line 20, with the Parallel 3, which is at the Point

Point of Interfection marked Z. The Space 32 fhall be the 23 Fathoms defired. Would you have 58? Take the Point of Interfection of 50 and 8, going from 8 quite to Y, where the Parallel 8 meets the tranfverfe Line 50.

115. This Subdivifion, and the Facility of taking any Numbers without Confufion by means of thefe tranfverfe Lines are Inventions fo commodious, that they are applied through the whole Extent of the Graphometer, which is without Difpute one of the perfecteft of our mathematical Inftruments.

116. The Service of thefe Inftruments is confiderably affifted; nay, the Ufe of them is even totally difpenfed with, by making a Collection of many certain Obfervations, which enable us, from a firft Meafure perceived in the Difpofition of the Angles, immediately to affign the other Meafures defired. We fhall here mention only the moft fruitful of thefe general Obfervations.

117. If you know the Value of one of the two Angels, that divide a Semicircle or a Quadrant, you know alfo the Value of the other, which is the Supplement or Overplus of the firft Number to 90 in the Quadrant, or to 180 Degrees in the Semicircle.

118. If, in a Semicircle (*Fig.* 28.) divided into three Angles, you know two of the faid Angles, one, for Inftance, of 50 Degrees, the other of 25, you know alfo the third Angle, which is 105; for 25 and 50, which make 75, being fubftracted from 180, the Remainder is 105.

119. The Angle at the Center, that is, the Angle which has its Vertex in the Center A. (*Fig.* 29.) has for its Meafure the Arch on which it ftands: For a Perpendicular in the Center, fuch as B A, forms two right Angles there, which are 90 Degrees each; and the fame Perpendicular being transferred obliquely from the Center A, into C, by exactly the Half of a right Angle, forms there an acute and an obtufe Angle, and the Obtufe 135 acquires the 45 loft by the other.

120. It is the fame with all the Angles formed by a Line falling on another, either at the Center of a drawn Circle, or at the Center of a Circle not drawn, but imaginary. But when a Line meets with another, in the Periphery, or any-where but at the Center of a Circle, the

Meafures

Measures change according to the Circumstances; but they still are the same in like Circumstances, and are determined without any Operation, by general Principles, which are very expeditious.

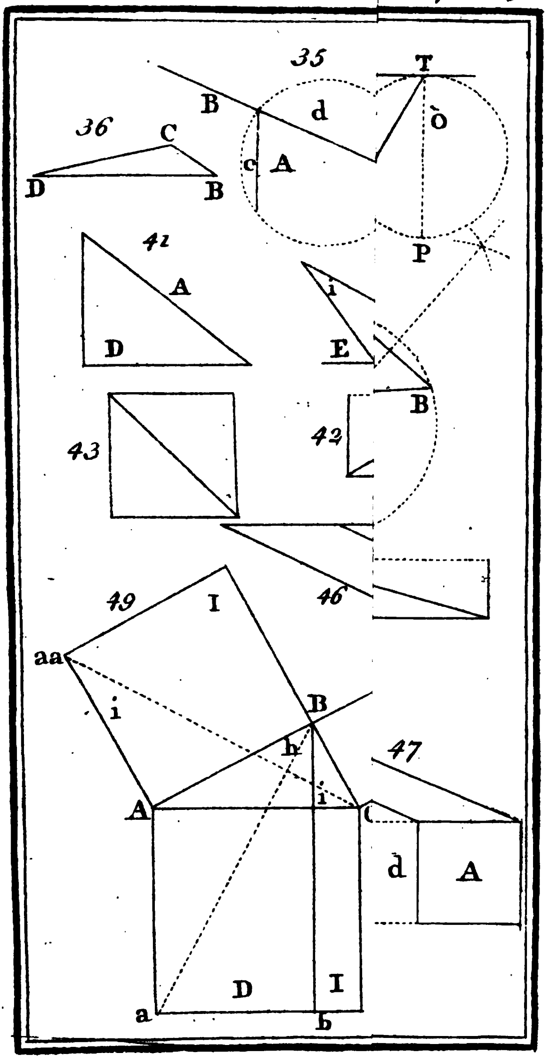
The Angles of the Segments.

121. A Tangent T (*Fig.* 30) that is, a Line which touches the Out-side of a Circle only in one Point T, makes with the Perpendicular P two right Angles, and with a Chord I, falling obliquely on the Point of Contact T, two unequal Angles, *viz.* One obtuse O, the other acute A. In the first Case, which is that of the Perpendicular P falling on the Tangent T, each right Angle has for its Measure the Half it contains of the Semicircle. In the other Case, *viz.* that of the oblique Line I falling on the Tangent at the Point T; the obtuse Angle O, comprehends the Arch of the greater Segment T P I, and has one Half of the greater Arch it comprehends for its Measure: The acute Angle A comprehends the Arch of the lesser Segment T A I, and has for its Measure one Half of the smaller Arch subtended by one of its Sides. For, as the Line P, which is perpendicular to the Tangent, makes two right Angles of 90 Degrees each, which is Half of the Degrees of the Semicircle comprehended by each of them, so does the oblique Chord I make with the Tangent T the two right Angles O A, equivalent to the two Angles of which they take up the Room: They have, therefore, (taken together) half of the whole Circle for their total Measure. Now, the Angle A, which is the acute, has lost that Part of the Value of the right Angle, which is given to the obtuse O. Therefore, since the right Angle had for its Measure one Half of the Semicircle it comprehended; the acute A must needs have for its Measure one Half of the Arch of the smaller Segment, and the obtuse O one Half of the Arch of the greater Segment, which, together with the lesser one, make the whole of the Circle: Otherwise, these two Angles would not have for their Measure one Half of the Circle as well as the two right Angles they replace.

The Angle at the Periphery.

122. The Angle at the Periphery, *Fig.* 31, which has its Vertex in the Circumference, and is also called the Angle inscribed in the Circle, such as the Angle M in this Figure, has for its

Measure


35
T
B
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36
C
c
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41
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43
42
46
49
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h
i
47
A
C
d
A
D
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a
b

Measure one Half of the Arch D it stands upon: For, the three Angles A M B formed upon the Tangent in a, fill up the Room of two right Angles, and have Half of the Circumference for their Measure. Now, from the foregoing Proposition, the Angles of the two Segments A and B have for their respective Measure one Half of the Arch they comprehend. Therefore, the Angle M, which is the Angle at the Periphery, has for its Measure one Half of the remaining Part of the Circle, that is, one Half of the Arch D it stands on. Whence it follows that,

The Angle at the Center.

123. The Angle at the Center a a, as D (*the same Fig.*) which, as it has its Vertex in the Center a a, must, (from *Propos.* 118.) have for its Measure the whole Arch it stands on, is double of the Angle at the Periphery M, since the latter having its Vertex in the Point (a) of the Circumference, must (from the foregoing Proposition) have only one Half of the Arch D it stands on for its Measure: whence follows another Proposition of great Use, *viz.*

124. All the Angles, such as A B C, *Fig.* 32. which have their Vertex at the same Periphery, and their Legs standing upon the same Arch, are equal, as they all of them have one Half of that Arch D, for their common Measure. It necessarily follows from the same Principle, that,

125. All the Angles that can be inscribed in a Semicircle, *Fig.* 33. are so many right Angles: The very Figure decides their Quantity at once, since having, all of them, their Vertex at the Periphery, and all their Legs standing on the two Extremes of the Diameter, they necessarily have one Half of the Semicircle for their common Measure; that is, 90 Degrees, (from *Propos.* 121.)

126. The Angle A, *Fig.* 34. which has its Vertex betwixt the Center and the Periphery, has for its Measure one Half of the Arch d e, on which it stands, and one Half of the Arch f g, which the two Legs of A prolonged over the Vertex stand on. For A being equal to B, which is vertically opposite to it, is also equal to C the alternate Angle of B between two Parallels (from *Propos.* 103.) Now C, which is at the Periphery, has (*from Propos.* 122.) for its Measure one Half of the Arch d h, that is, one Half of d e, and one Half of e h; and e h is equal to

f g,

f g, (from *Propos.* 77.) because they are two Portions of the same Circle between two Parallels; Therefore the Angle A, which has its Vertex betwixt the Center and the Periphery, has for its Measure one Half of the Arch d e, which its Legs stand on, and one Half of the Arch f g, on which stand the same Legs prolonged over the Vertex.

127. The Line which traverses the Circles and go out of it is called *Secant.*

The Angle B, *Fig.* 35, formed by the Chord c, and by the external Part of a Secant d, has for its Measure, one Half of the Arch subtended by the Chord c, and one Half of the Arch subtended by the Remainder of the Secant d. For the acute A and the Obtuse B are equivalent to two right Angles, and have, if taken together, one Half of the whole Circle for their Measure. Now, the Angle A being at the Periphery (*Prop.* 122,) has one Half of the Arch it stands on for its Measure: Therefore, the obtuse Angle B has for its Measure one Half of the whole Remainder, or, which is the same, one Half of the Arch c subtended by the Chord; and one Half of the Arch d subtended by the internal Part of the Secant.

Although you may know the Value of these and all other imaginable Angles, by placing their Vertex at the Center of a Circle drawn for that Purpose; it is nevertheless convenient to dispense, as much as possible, with any new Operation, by Help of a few general Maxims which accustom the Mind to discern at one View the Quantity of an Angle, in such or such Circumstances. What goes before is sufficient to inform us, that the most general Means of knowing presently all Sorts of Angles, are, 1. The carefully examining whether they have their Vertex at the Center or Periphery. 2. The Comparison made of an Angle with the two right ones, which being always known, may be a Help to find that out. 3. The Comparison made of an Angle with another formed upon a parallel Line, which last once known reveals its alternate, or that vertically opposite to it, in short, its equal.

The Triangle.

128. The Triangle, which is a Space comprehended under three Lines united in three Angles, procures new Facilities and innume-

innumerable Methods, of measuring any Extent; because the known Sides will discover the Angles, and the Knowledge of the Angles will let you into that of the Sides unknown.

129. Three Points of a Line B C D taken at random as it were; if they do not belong to one and the same right Lines may be united by three Lines and form a Triangle. Let us call the three Points or the three Angles B C D. *Fig.* 36.

130. The Side opposite to the greatest Angle is commonly called the Base or Hypothenuse, as the Side B D, opposite to the obtuse Angle C: However, there is no Side in any triangular Figure, but what may be called the Base of the Angle which stands on or is opposite to it.

131. The three Vertices B C D of any imaginable Triangle, necessarily make three Points of a Periphery; and as the Value of the three Arches is easily known, it is made Use of to find out the Value of the corresponding Angles. That three Points becoming the three Vertices of a Triangle are all three within the Sweep of a regular Periphery, is evident: For (by *Propos.* 70.) if you cut the Side B C and the Side C D, *Fig.* 37, into two, the Perpendiculars prolonged towards the same Side B D will incline one to another, and cut each other. Now, the Point E of the Intersection is equally distant from B and C, since it makes Part of the Perpendicular erected on the Side B C. But, it is also equally distant from C and D, since it is likewise Part of the Perpendicular on C D. Therefore, the Point of Intersection E is equally distant from B C D: It is then the common Center of three Radii, or of three equal Openings of the Compasses B C D. But, having three Radii united in a common Center, is having the whole Circle. Therefore, the three Vertices of any Triangle are at the Circumference of a Circle already drawn, or which may be drawn.

132. The Circle which takes in the three Vertices is easy to be known, since they help us to find both the Center and Radius by the foregoing Operation.

133. The three Angles of a Triangle being at the same Periphery, stand upon the three Arches which make up the Whole of the Circle; and (from *Propos.* 122.) they

they have for their Meaſure one Half of theſe three Arches, or Half of the whole Circle. Whence it neceſſarily follows that;

134. The three Angles of any Triangle are equal to two right ones, having, as well as two right Angles, the whole Semicircle for their Meaſure.

135. A Triangle can never have more than one right Angle: For, ſhould it add ever ſo ſmall an acute Angle to its ſecond right one, it would exceed the 180 Degrees which make it equal to two right ones.

136. Much leſs will a Triangle admit of more than one obtuſe Angle.

137. If one of the Angles of a Triangle is a right Angle, the Sum of the other two is 90 Degrees, ſince they together are equal to a right Angle (from *Propoſ.* 134.)

138. If the Triangle be equiangular, or has three Angles equal, each of them is acute; and placed on an Arch of 120 Degrees, one half of it, or 60 Degrees, is their Meaſure, (*Fig.* 38.) otherwiſe they would not be equal to two right Angles, which have for their Meaſure three times 60, *i. e.* 180.

The Iſoſceles.

139. If the Triangle has two Sides equal (which is called an Iſoſceles Triangle) it has, alſo, two equal Angles; then if you know one Angle, you know the whole; for the two others make up the Meaſure 180; and if you know one of the equal, you know the other, and conſequently the third which makes up 180; but if it be the unequal, the Surplus as far as 180, is divided between the two equal.

140. If one of the three Angles of the Iſoſceles Triangle be a right Angle, and the other two equal, they are acute, and each of 45 Degrees, double Supplement from 90 to 180, (*Fig.* 39.)

141. By producing which Side you pleaſe of a Triangle, as *Fig*, 40. o c E, the Angle E, formed by the Side produced, is called external, c internal or conjunct, the two others internal, o, i, are called oppoſite.

142. The External E, *Fig.* 40. is equal to the two Oppoſites o, i; for the external E, and the conjunct c, are together as good as two right Angles; but (by the 133.) the three Angles of a Triangle are equal to two right

right Angles; therefore the internal c, must be of the same Value with the external, as with the two opposites, and, consequently, the external is equal to the two opposite internals.

143. If all Triangles can be conceived as inscribed in a Circle or terminating by their three Extremes at the Circumference of a Circle, it follows, that the three Sides of every Triangle are the three Chords of the three Arches, which together make the whole Circle circumscribed at the three Extremes.

144. Therefore he that knows the exact Position of the three Extremes of a Triangle, in their Circle, and one Side, knows likewise the Value of each Angle, and the Length of the three Sides; for he that knows one Side, and the Position of the three Extremes in such a Circle, knows the three Arches opposite to the three Angles. To know the Arches is knowing the Angles, the Value thereof they measure in half, since those Angles have their Extremes at the Circumference. To know the Arches, is knowing, likewise, the Chords which have the same Measure with the Arches: therefore it is knowing, also, the Length of the Sides, which does not differ from the Chords, and is measured, in small, by the same opening of the Compasses with the Arches. To know a Side, and the Position of the three Extremes in the Circle, is, therefore, knowing the whole Triangle.

145. It even suffices to know the Value of one Angle, and the Length of the two Sides, to know the other Side, and the two Angles remaining; for he that knows one Angle, and the Length of two Sides, knows the Point of the Circumference whence the two Sides proceed, and the two other Points where those Sides arrive in the Circle; it is, therefore, knowing the three Points desired (by the *Fig.* 131.) it is therefore, knowing the Value of the three Arches; but the Arch, opposite to the Angle known, measures the Chord or Side remaining to be known; and the two Sides, the Length of which is known, are the Chords and Measures of the two Arches, whose Halves serve to fix the Value of the two Angles required. Therefore you have the whole Triangle.

146. Likewise one that knows one Side and two Angles knows the whole Triangle; that Side known gives you

by

by its Extremes two of the Points desired; but you don't know yet where the third is, nor how many Degrees are to be reckon'd in the Arch of which that first Side will be the Chord; but you will soon learn it. The Knowledge you have of the two Angles, teaches you how much the two other Sides unknown are inclined on the preceding, or how many Degrees they contain; you will know, therefore, that the Degrees remaining, as far as 360, are the Value of the Arch, whose Chord was already known to you: You will know, likewise, immediately, in what Point of the Circle, those two new Chords will meet; you will have, therefore, the three Points desired, and with them the Knowledge of the three Arches, the three Sides, and the three Angles.

147. It is true, that with the Knowledge of the Angles, and, consequently, of the true Inclination of the Lines, you may soon find your three Points, in working on Paper, or in small on the Ground; but how will you fix, without Mistake, the just Point of Concourse of two Lines on a Ground of 5 or 600 Perches; besides that, you may be obstructed on the Ground by a Wood, or a River, or any other such Obstacle, so far as to make it impossible to gain the Point which reunite the two Lines. The Remedy, then, is to draw, in small, on the Ground, or Paper, a Triangle; one Side thereof shall have as many small Parts of your Scale, as the Side known of the greater Feet, or Poles, or Perches; then with the Protractor on the known Side of the lesser Triangle, you must incline the two other Lines according to the Number of Degrees of their Arches, which is the same in small as in great; you will know, then, where is the Point of Concourse, the two Lines given it by the Measure of their respective Inclination: Therefore you have, in the lesser Triangle, the three Points necessary to know it entirely; and as many small Parts of your Scale as you find on each Side, with remaining Parts or without, so many Perches you will have, with the remaining Parts or without, on the Sides of the greater.

Incommensurables.

148. I say that the common Measure which shall be taken on a known Side to be carried on the other Sides, will be found there, either in small or great, a Number of times, with remain-

remaining Parts, or without; because there are Lines which cannot be compared by a common Measure to be there precisely a number of Times without some Surplus; and, then, that Surplus is not precisely assignable. It is a surd Number, very near a Quarter, or a Third, or other Part, but which always differs, a little from it. Such is, for Example, the Base of a rectangular Triangle compared to either of the Sides of the right Angle; take in the Line D, which is one of the Sides of the rectangular Triangle A D, *Fig*. 41. the smallest Measure you will, *viz*. half a Line, which, I suppose, is found in it twelve Times; carry it on the Hypothenuse A, it will be found there, not only a greater Number of Times than you can determine, but always with a small Surplus, and a fractionary Number, which has not, even, a just Precision. If you take a smaller Measure, you will find it so many Times in the Base A, and always with a Surplus, but so small, that it is scarce to be minded, there being, then, all the Correctness sufficient for human Works. In the Comparison of those Lines, we approach, still nearer and nearer, a common Measure, which can be numbered so many Times in the one, and so many Times in the other, almost without remaining Parts; but that Surplus is unavoidable, and at the same Time unassignable: Hence the Name of Incommensurable given to those Lines.

149. This, however, does not hinder the Advantage and Correctness of the Scales of Comparison; for as you will find in the Base of a small Triangle, thirty Times, and very near a Quarter or a Third, the Line, Inch, or other Measure, which is the common Part taken in your Scale, you will have likewise, thirty Perches, and very near a Quarter or a Third in the Mensuration in great.

150. The Knowledge of Triangles leads to that of Parallelograms, the double of them; for if you multiply the Side of any Angle of a Triangle by its other Side, you will form of it a quadrilateral Figure, whose opposite Sides are parallel, which is called a Parallelogram, *Fig*. 42. Parallelograms.

151. The Base of the Angle, whose Sides you double, is then called a Diagonal, because it passes from an Angle of the Parallelogram to the The Diagonal.

the opposite Angle, and divides it into its two Triangles, and shews that it consists of two Triangles equal and approximated.

The Square. 152. If the Angle whose Sides are multiplied, be a right Angle, and the Sides equal, it is a Square which has four right Angles, and four Sides parallel and equal, *Fig.* 43.

The Rectangular, or long Square. 153. If one Side of the right Angle be multiplied by another shorter, the Parallelogram produced by it, *Fig.* 44. is a Rectangular, or long Square, which has its four Angles, right Angles, and those of its Sides opposite to it, equal between them and parallel.

The Rhombus, or Lozenge. 154. If the Angle whose Sides you double, be acute, or obtuse, and the four Sides equal, the Parallelogram is a Rhombus, or Lozenge, *Fig.* 45. which has two opposite Angles acute, and two obtuse, all its Sides equal, and the Opposites parallel.

The Rhomboides. 155. If one Side of the acute or obtuse Angle be longer than the other, *Fig.* xlv. it produces a Rhomboides, which has two acute Angles, and two obtuse, its Sides unequal, but the Opposites parallel.

156. In many Cases it is easy to know at once, the Value of all these Parallelograms, by the Facility of reducing them to the Value of a Square by multiplying one of its Sides by itself.

One may be puzzled to find the Measure of the Rhomboides B C, *Fig.* 46, but one may judge of it by reducing it to the Value of the Square A B, by the following Means.

157. Parallelograms placed on the same Base between parallel Lines are equal.

The Square A B, and the Rhomboides B C, *Fig.* 46, are both on the Base E, and between the Parallels E F; from these, let us suppose, the lesser Angle B taken off, there remain then two Triangles, *viz.* the Triangle A D, and the Triangle D C, perfectly equal, since their Angles, and their Sides are equal. Of those two equal Triangles take off D, which is common to both, there will remain as much to one as to the other: therefore the quadrilateral

teral remaining A and C are equal. Then if you reſtore B, to the quadrilateral A, and afterwards conſider B, as added to the quadrilateral C, they acquire, by Turns, the ſame Value B, and as they were already equal before that Acquiſition, they are ſo ſtill after the Addition of a Thing equal on either Side; therefore Parallelograms on the ſame Baſe, between Parallels, are equal.

158. Parallelograms placed on an equal Baſe, and of an equal Height are equal; for the Baſe being the ſame, it is indifferent whether the Height be taken under a Line or above it, provided that Height be the ſame. Let the Square A, and the Rhomboides B, *Fig.* 47. ſerve for an Example of this, which I ſuppoſe at the Height D, equal to E, the ſame with d the Height of the Square A; the Baſe c of the Field A, is the ſame with the Baſe C of the Field B, the Height D of the Rhomboides B is the ſame with the Height d of the Square A; therefore Parallelograms on an equal Baſe, and at the ſame Height are equal. This ſame Truth, which is of great Importance, may become more ſenſible by the *Fig.* 48. the Square A, and the Square B are equal, ſince they have all their Sides equal; but the Rhomboides C, which is on an equal Baſe, and has the ſame Height, is compoſed of two Triangles, which are the ſame with thoſe the Square B is compoſed of; therefore the Rhomboides C is equal to the Square B. The Square A therefore being equal to B, is likewiſe equal to the Rhomboides, which has a Baſe and a Height equal to thoſe of the Square.

159. Triangles on the ſame Baſe, and at an equal Height are equal; for what is affirmed of the wholes may be affirmed of the halves; but the Triangles are the halves of the Parallelograms.

160. The Square formed on the Hipothenuſe of a right Angle, *Fig.* 49, is equal to the two Squares formed on the two other Sides.

To demonſtrate it; from the Vertex B of the right Angle A B C draw a Perpendicular B b; the Square formed on the Hypothenuſe A C, will be cut by that Perpendicular into two Rectangles D and E, which together are the ſame as the whole Square; but D is equal to the Square f, and E is equal to the Square G, both produced from the two other Sides of the right Angle multiplied

by themselves: That D be equal to f, is evident from what precedes. The Triangle h A h is equal to the Triangle i A i, since they are on equal Bases, and at equal Height, one of them being on the Base A a, and the other on the Base A C, equal to the Base A a; and the Height of the one A a a being equal to the Height of the other A B: but the Triangles h A h, is equal to half of D, which would be formed by the Diagonal, if it was drawn from a into i, since the Triangle, which would make the half of that Square, would have the same Base A a, and be between the same Parallels A a, B b, with h A h; likewise half of f, or the Triangle, which would be taken by a Diagonal from a a into B, would have the same Base A a a, and be between the same Parallels, *viz.* A a a, B b b, B C, with i A i; therefore half of D is equal to half of f; thus D is equal to f, and for the same Reasons, E is equal to G; therefore the whole Square, on the Hypothenuse A C of the right Angle, is equal to the two Squares of the Sides.

Here we are affected with a Surprise, which, at first seems not easy to be removed; for how is it possible that Squares formed on the Curve A B C, necessarily greater than the right Angle A, are together but equivalent to the Square formed on A C? To which I answer, that the Advantage of A C proceeds from the whole Line A C, being multiplied by itself; and each of its Parts repeated as many times as there are Parts in the whole; whereas the Line A B C is not multiplied but by Parts lesser than the whole, *viz.* A B by itself, and B C by itself. Let us suppose A C of ten Inches, but cut into two Pieces, one of 7, and the other of 3; multiply 7 by 7, you will have 49; multiply 3 by 3, you will have 9, in all 58; whereas if 10, the same Number as 7 and 3 together, be multiplied by the whole, then 7 instead of being multiplied only by 7, shall be multiplied by 10, and 3 likewise; so that instead of 58, the Product will be 100. It is quite contrary, (in which consists the Disadvantage of the Curve A B C,) in the Comparison made between the Product of its two Pieces, and the Product of the Total A C. Let us suppose one of those two Pieces, or the Side A B, of about eight Inches, and the Side B C of about six, which is together much more than 10, but instead of

of multiplying the whole, which is near 14, by the whole, you only multiply the two lesser Sums by themselves, *viz.* about 8 by 8, which gives near 36; together they will only give you about 100, whereas if 8 and 6, which are 14 by 14, were multiplied, as you have multiplied 7 and 3, or 10 by 10, the Product of the total Curve A B C, would be 196.

If in these Calculations I am frequently obliged to make use of the Words *about*, and *very near*, it is because the Square of the Hypothenuse being of ten Inches multiplied by ten, and the Product thereof 100, it cannot happen that the Square of one of the other Sides, be reduced to a Root which is a precise Sum of so many Inches. Squares are comparable and commensurable between themselves, but it is not by a small Measure known which can be so many times in the Hypothenuse, and so many times in the Sides, which are uncommensurable.

How can we be able then to compare them? We have Recourse for it, to a Scale of Parts as small as the light Surplus; that surd and unassignable Number, which disturbs the exact Comparison in Number, is, at last, considered as nothing.

To that beginning of a geometrical Chain, we add only another Link, which is that of the Radii, Sines, Secants, and Tangents, the Accounts whereof, being always constant and very numerous, become the Foundation of the most perfect Geometry.

161. We call the Complement of an Angle, or of an Arch, the Quantity, such as a B A, whereby our Arch, as A V, is less than a quarter of the Circle B V, *Fig.* 50.

162. We call Complement to the Semi-circle, or Supplement, the Quantity A D, whereby an Arch, such as A V, is less than the Semi-circle V A D.

163. A right Sine SA of an Angle, such as ARV, or of an Arch, as AV, is a Perpendicular, carried from an Extremity A of the Arch AV, on the Diameter, or Radius, which passes through the other Extremity V of the same Arch; one can also say that the right Sine A S, is half of the Chord which supports double of the Arch A V. Sines.

164. A versed Sine is that Part of the Radius, comprized between the Extremity V, of the Arch A V, and its right Sine A S.

165. A Sign of Complement is the Sine of the Arch A B, the Complement to a quarter of the Circle.

166. The total Sine B R is that of a quarter of the Circle B V, or of the right Angle B R V, and does not differ from the Radius itself. The Radius is half of the Diameter, and we have proved, that all the Chords which do not pass through the Center are shorter than the Diameter; therefore the total Sign being half the Diameter is longer than the other Sines.

Tangent. 167. The Tangent of that Arch, or of the Angle A B V, is perpendicular to the Extremity of the Radius V, and is terminated by the other Radius R A, produced as far as T.

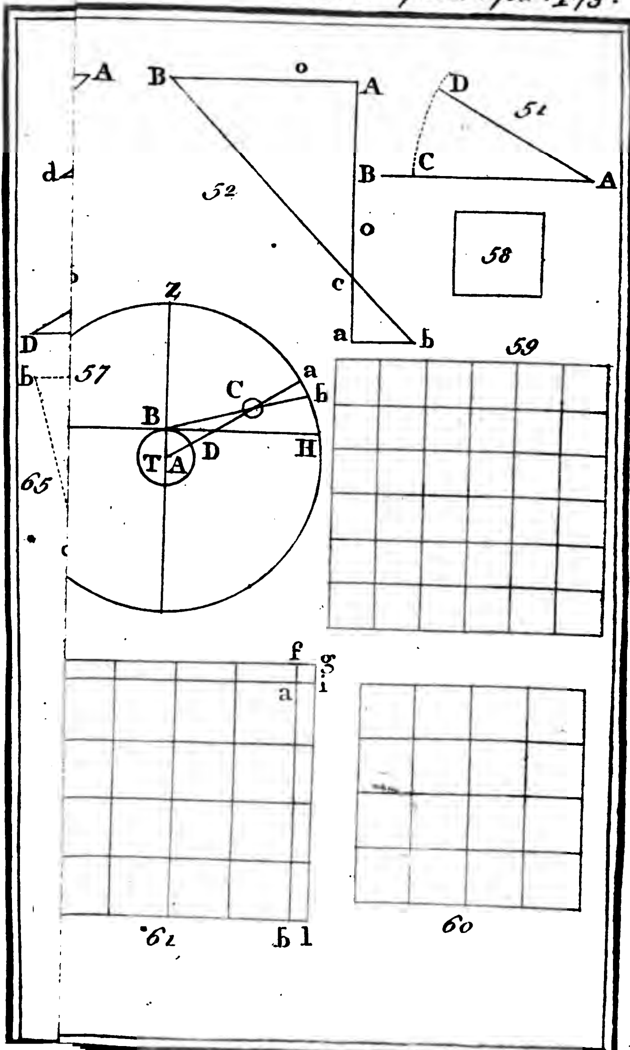
Secant. 168. The Secant is that second Radius produced R A T, which terminates the Tangent T V.

169. To compare those Lines together, and find one by the Knowledge we have of the other; we divide the Radius into 1000 Parts or into 100,000 Parts, or more; and though those Lines be immeasurable between themselves by means of those small Parts, we fix, notwithstanding, their Report with an Exactness, which approaches very near a Precision; and if they have any Imperfection, in Handcraft-works, it is so very small, that it is not to be minded.

170. The Squares of the right Sine, and of the Sine-Complement, taken together are equal, to the Squares of of the Radius: Proof;

A C R S is a Parallelogram by its Construction, and has four right Angles; it is cut into two Triangles of which the Radius R A is the common Hypothenuse; whence it follows, that the Sine-Complement, and A is equal to the other Side parallel R S; but (by 159) the Square of the Hypothenuse B A, is equal to the two Squares formed on the two other Sides of the Rectangle A S R; therefore the Square of the Radius A R, is equal to the Square of the Sine-Complement C A, and of the right Sine A S, it is the same with the Secant, compared with the Semidiameter and the Tangent.

I leave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I leave you to judge, by these few Instances, of the Conveniency of the Proportion that may be found in those Lines, which may be drawn on every Side; they are compared between themselves, in their Triangles, in their Squares, and otherwise: The Proportions thereof are hypothetical, and according to the Scales: We suppose the Radius composed of ten Thousand, a hundred Thousand, ten Million of Parts taken in a Scale. The smaller those Parts, the nearer the Comparison of Immeasurables approaches a Precision. If the right Sine has so many Parts, there are so many such Parts in the Sine-Complement, so many in the versed Sine, so many in the Radius, so many in the Secant, so many in the Tangent; and reciprocally a single Measure taken, leads to a great Number of other Measures: one can force his Way every where; and to facilitate, at once, all those Calculations, we make Use of Tables already made, where we find how many Parts the Sines, Tangents, and Secants, must have in such and such Suppositions.

The Use of Measures.

HERE is the Manner of Drawing on Paper, an Angle equal to another Angle, which has been observed on the Ground. Suppose that Angle to be of 30 Degrees, we must draw on the Paper one indefinite Line AB, *Fig.* 51. make afterwards the Compass of an Opening equal to the Semidiameter of a Protractor, and describe from the Point A, as a Center, the indefinite Arch CE; take, then, with the Compass on the Circumference of the Protractor, the Interval found between 0, and 30 Degrees, and carry that Interval from C into D; Draw the Line AB; and the Angle CAD will be of 30 Degrees, since it has been taken on the Protractor, of which AC is the Radius, and the Arch CD of 30 Degrees.

The Lengths, or Lines, are measured on Paper, by Means of a Rule, divided (by *Propos.* 112.) into a great Number of equal Parts: for that effect the Compass is opened betwixt the Extremities of the Line, and that opening of the Compass, equal to the Length of the Line,

is carried on the Scale; by which Means we find, how many Parts it contains.

To measure an acceſſible Diſtance.

A Diſtance is meaſured on the Ground, when it is acceſſible, by its two Extremities, by applying to it ſucceſſively a Rope, or ſmall Chain, divided into equal Parts, as Feet, Roods, or Perches, or other known Meaſures, and thence we find, how many of thoſe Parts that Diſtance contains.

If the Diſtance be acceſſible but by one of its Extremities, it muſt be found in this Manner. Let us ſuppoſe that you muſt find the Diſtance A B. *Fig.* 52. which is acceſſible only by its Extremity A. Firſt, you muſt place the Center of the Graphometer, or Semicircle, at the Point A, ſo that the Point o, whence you begin to tell the Degrees, be touched by the Alidad, or moveable Index, which muſt be directed from A into B, and afterward from A, toward ſome other acceſſible Point, as C, whence you may view, at the ſame Time, the Points A and B. Leave the Graphometer in the Situation you have given to it in viewing along the Line A o B, and obſerve of how many Degrees is the Angle A between B and C. Secondly, You muſt go in a right Line to the Point C, in meaſuring with a Chain, or a Rope, divided into Feet, or Perches, the Diſtance A C, and obſerve it; you muſt afterwards ſtop the Graphometer, at the Point C, ſo that its Center anſwers to that Point, and direct it in ſuch a Manner, that the Alidad being at the Point o, whence you begin to reckon the Degrees, you may ſee through the Sights the Point A, and leaving the Inſtrument in that Situation, turn the Alidad till you can diſcover through the Sights the Point B, and obſerve the Angle A C B, in taking always for the Vertex that of the three Letters which is in the Middle. Thirdly, After that Operation, you muſt make a ſecond on Paper; by taking with the Compaſs on a Rule, divided (by *Propoſ.* 112.) into equal Parts, ſo many of thoſe Parts as the Length A C, which has been meaſured on the Ground, contains Roods, or Perches; and after you have drawn an indefinite Line, take from it a C, equal to the Opening of the Compaſs; you muſt afterward make the Angle a C b, equal to the Angle A C B, by Means of a Protractor; making, in the ſame

same Manner, the Angle C a b, equal to the Angle C A B, and the Lines a b, C b being drawn, will cut each other at the Point B, and the three Lines C a, a B, C b, form a Triangle, which will have Conditions exactly like those of the Triangle A C B: thus the Sides of the lesser Triangle will be in the same Relation with those of the greater: and you will know, that if c A B, be equal to A C, likewise C a is equal to a b; that if a c contains once a b, and a third of the same Line; A C contains, also, once, the Distance A B, and a third of the same Distance. Therefore if the Length of the Side a b, be taken with the Compass, the Opening being carried on the Rule of equal Parts, the Number of those Parts it shall contain, will shew the Number of Roods, or Perches, contained in the Distance A B.

Let us suppose we have found that the accessible Distance A C, contains 100 Roods, the Side A will contain 100 equal Parts of the Rule: Suppose, likewise, that after the Triangle a C b has been formed on Paper, according to the Method prescribed, we find, that the Side b a contains 75 equal Parts of the Rule; we know immediately, that the Distance A B contains 75 Roods, or Perches, because the Sides of the greater Triangle cut each other in the same Conditions as those of the lesser; that, therefore, since the Side a C of 100 Parts contains the Side a b of 75, once and a third; likewise the Side A C, of 100 Roods, or Perches, contains the Side A B, once, and a third: then the Distance A B is of 75 Roods or Perches.

We must be exact in making the Angles on Paper precisely of the same Bigness with those which have been formed on the Ground, otherwise the Operation would be of no Use towards finding the true Distance A B: if the Angle a C b was greater than the Angle A C B, the Side a b would be greater; we should judge, then, that the Distance A B would be greater than it is in reality; the contrary would happen if the Angle a C b was made lesser than the Angle A C B.

If we will determine on the Ground itself the Distance A B, *Fig.* 53, after having formed the Triangle A C B, Care is to be taken that we extend ourselves towards the opposite Side, and produce A C as far as into a, so that a C be equal to A C; and make on the Ground the Angles

e C b, C a b, equal to the Angles A C B, C A B, in viewing through the Sights at the same Point b: with the Help of the Graphometer, kept successively in C and a, measure afterwards the Distance a b, which will be equal to the Distance A B; since the Triangles A B C, a b C, are equal in all. To have the Point b, where the visual Ray must terminate, a Signal must run along B C b, till it be perceived through the Sights of the Alidad, when it makes with a C, the Angle C a b, equal to the Angle C A B.

If the Distance A B, *Fig.* 54, is inaccessible by its two Extremities, it may, also, be known by drawing a Figure on the Ground, and afterwards in small on Paper. Be the Distance A B inaccessible by its two Extremities A B, which we want to know, we must chuse a Ground on which we can measure with Ease, the Distance C D accessible by its two Extremities C D, at each of which one may discover, at the same Time, the Points A and B. When we are at the Point C, we must take the Graphometer, and measure three Angles, in viewing through the Sights the Angle A C B, which is between the visual Rays A C, C B, which ends at the Extremities of the Distance A B; the Angle A C D, which is betwixt the visual Ray A C, and the Distance C D, which we propose to measure with the Chain or Rope; and the Angle B C D, which is betwixt the visual Ray C B, and the Distance C D. That Operation done, we must go directly to the Point D, in measuring the Distance C D, and observe it when we are arrived at the Point D: There we must erect the Graphometer, or Semicircle, and take two Angles, *viz.* the Angle A D C, which is betwixt the visual Ray R D, and the Distance C D; and the Angle B C D, which is betwixt the visual Ray B D, and the same Distance C D: We may end the Operation on the Ground, or transfer the Figure A C D B on Paper. First, If the Operation be ended on the Ground, it must be repeated; but to avoid a too great Length, when the first Station is made in C, we must take towards the Sides, opposite to the Distance C D, the same Angles, *i. e.* the Angle a C D, equal to the Angle A C D, a C b equal to the Angle A C B, and the Angle b C D equal to the Angle B C D. Going afterwards to the Point D, we must measure the Length C D, and at the second Station

tion in C, make the Angles C D a, and C D b be equal to the Angles C D A, C D B. But to have the Point a, where the visual Rays C a, D a terminate, we shall be obliged to make a Signal run on C a, till it be perceived through the Sights, the Alidad making with C D the Angle C D a, equal to the Angle C D A: We must likewise make to run on C b, a Signal till it be perceived through the Sights of the Alidad, when it makes with C D the Angle C D b equal to C D B: Measuring afterwards the Distance a b, which is equal to the inaccessible Distance AB, since the two Figures A C D B, a C D b are equal in all their Parts.

To transfer, in small, on Paper, the Measure of a Piece of Ground.

To transfer the Figure A C D B, in small, on Paper, *Fig.* 54, and LIV. and determine, by Means of Angles taken on the Ground, and a Scale of equal Parts, the inaccessible Distance A D. 1. An indefinite Line must be drawn, taking with the Compass on the Scale, as many Parts as the Base C A contains Roods, or Perches, and carry that Opening from c into d: Suppose that C A, on the Ground, contains 100 Perches, c d on Paper, will contain 100 equal Parts. We must make afterwards, the Angle a c d equal to the Angle A C D, which has been taken on the Ground; and the Angle b c d, will be found thereby, equal to the Angle B C A, which has been taken on the Ground: We must make, also the Angle c d b equal to the Angle C A B. And the Angle a d c to the Angle A D C, which has been taken on the Ground; the Intersections of the Lines a c, a d, b c, b d, will determine the Length of the Line a b, which being carried on the Scale of equal Parts, will shew the Number of Fathoms contained in the inaccessible Distance A B; for that Distance will contain as many Fathoms as the Line a b contains equal Parts; because, in the Figures A B D C, a b d c, the Lines cut each other in the like Circumstances, differing only in Bigness betwixt themselves, but not in Number.

In the same Manner may be shewn the Height of a Column, a Pyramid, of a Tower, of a Mountain, of a Tree, &c. when one can't approach the Foot of it. It suffices for that Operation, to take the Angles A D C, A C B, or A C D, and measure with the Chain, or Rope, the

Length C D, drawing an indefinite Line on Paper, on which ſhall be taken ſo many equal Parts, as the Line C D contains Fathoms, or Feet, making the Angles a d c, a c d, equal to the Angles A D C, A C D, and the Lines a c, a d, being ſufficiently lengthened, will cut each other at the Point a, from which drawing, on d b, the Perpendicular a b, will be found, by Means of that Line, the Height A B; for if the Line a b, be carried on the Scale of equal Parts, it will be known that A B contains as many Fathoms or Feet, as a b contains equal Parts. By carrying on the ſame Scale the Lines a c, a d, we ſhall find, likewiſe, the Length in Fathoms, or in Feet, of the Diſtances A C, A D.

The Height A B, could alſo be determined on the Ground, by raiſing a Triangle equal to the Triangle A C D; and by drawing from the Vertex, a Perpendicular B D, it would be equal to A B.

In theſe Operations, the Angles either too acute, or too obtuſe, muſt be avoided; for as, in raiſing theſe Angles, one cannot help falling into ſome Error, by making them either greater or ſmaller than thoſe which have been obſerved, and, beſides, in taking the Angles on the Ground, Faults are alſo committed; it is proper to obſerve, that thoſe which give the Angles too acute, or too obtuſe, are greater than the Errors committed in taking the Angles which deviate much from thoſe two Extremities.

To Meaſure a heavenly Body, *Fig.* 57.

In the ſame Manner might be taken the Diſtance of a heavenly Body from the Earth, if an acceſſible Diſtance great enough could be meaſured on the Ground, but the whole Diameter of the Earth is too ſmall when compared with thoſe inacceſſible Diſtances. One muſt then, to determine them, employ the whole Diameter of the Earth, or very near the whole Diameter, and obſerve with all the Care poſſible, the Angles which the Diameter of the Earth, or a Line drawn from a Point of its Surface, as diſtant as poſſible from the firſt, would make with the viſual Rays, carried from thoſe Points to the heavenly Body: But as ſuch a Thing is not practicable, as well on Account of the Difficulty of meaſuring on the Earth a ſufficient Length, as becauſe the heavenly Body changes con-

tinually

tinually its Situation with regard to those Points, that Method cannot make us discover the Distance of a heavenly Body from the Earth. Astronomers, therefore, have Recourse to other Methods: The Diameter, or Semidiameter of the Earth, must notwithstanding enter into it: That, which we are going to give an Idea of, is proper to make one conceive, without long Reasonings, what Method one may take to determine the Distances of the heavenly Bodies from the Earth.

It is well known, that the Planets (which are the only heavenly Bodies we measure here, the fixed Stars being at so great a Distance, that it has not been possible, yet, to know, or even guess at their true Distance from the Earth) it is well known, I say, that the Planets describe, in their periodical Revolutions, Circles which cut the Equator, and therefore make half that Revolution in the northern Part of the World, and the other half in the Southern. Therefore in each Revolution a Planet is found twice in the Circle of the Equator: Astronomers know, besides, by the Duration of those Revolutions, and observing by the Interval the diurnal Motions of these Planets, the Moment they are in the Equator, or at the Point where their Orbits cut that Circle. Suppose, then, that an Astronomer knows the Moment when the Moon is at the Equator; he will be able to know, what is its Distance from the Earth. The smaller Circle T represents the Earth; A is the Center, B the Point of the Observer; C the Moon at the Moment she is at the Equator; D the Point, or Line, carried from the Center of the Earth to the Moon, cuts the Surface of the Earth; O H the sensible Horizon; the great Circle represents the Firmament, or Place of the fixed Stars. Since the Point C is a Point of the Equator, he that makes the Observation and placed in the Center A, directs his Sight along one Ray of the Equator, the Earth being supposed transparent like the Air, would see the Moon at the Equator in C: therefore A C is a Ray of the Equator, and D one of the Points where that Circle cuts the Surface of the Earth: But we know the Distance from the two Points of the Surface of the Earth, to the terrestrial Equator, or, at least, we may know such Distance as often as we will, by observing the Altitude of the Pole, with regard to the Place where the Observation

is made; for a Person under the Equator, has the two Poles in the Horizon; therefore as much as he goes from the Equator towards the Pole, so much the Horizon declines under that Pole; therefore the Altitude of that Pole is like the Latitude, or Distance of a Place with regard to the Equator; therefore we know the Arch B D, the Distance of the Observer, with regard to the terrestrial Equator, and we know, consequently, the Angle D A B, which is measured by that Arch. Besides, he that makes the Observation in B, measures the Angle O B C, which the visual Ray B C, makes with the Horizon O H, at that very Moment the Moon enters the Equator; then the Observer in B, knows the Angle O B C, and the Angle B A D, or B A C, which is the same. Besides, by the Propensity of the heavenly Bodies towards the Center A of the Earth, according to Directions perpendicular to the Surface of the Earth, or perpendicular to the Horizon O H, the Angle A B o is a right Angle, because B A, which represents one of those Directions, is perpendicular to O H: therefore if to the Angle A B C, be added the Angle O B C, the total Angle A B C, which is composed of two Angles known, will also be known: therefore in the Triangle A B C, we know the two Angles A and B. Moreover, the Semidiameter of the Earth is known: therefore if you draw on Paper a Line, A B, which represents that Semidiameter, and make with all the Care possible the Angle observed A and B, the Lines A C, B C, in cutting each other at the Point, will determine into Diameters of the Earth, the Distances of the Moon at the Point A, and the Center A of the Earth. The greater the Line A B is, which represents the Diameter of the Earth, the more exact the Operation will be. But because the Angle A C B is very acute, we must not expect to be capable to determine exactly those Distances by a mechanical Operation in tracing a Triangle.

The Parallax. The Angle A C B, is called by Astronomers, Parallax, *i. e.* Difference of Aspect; because an Observator placed at the Center of the Earth, would see the Moon in a Place of the Heavens, different from that where the Observator placed in B, sees it: for the Observator in B, sees the Moon in b among the Stars, and the Observator in A would see it in a. Astronomers,

to

to determine the Distance of a heavenly Body from the Earth, search, First, its Parallex, which being known, it is easy to find its Distance from the Earth: for in the Triangle A B C, is known the Angle of the Parallex A C B, and the Angle A B C; because the Angle C B A being known by Observation, it is easy to know the Angle A B C: the Semidiameter of the Earth is also known: therefore the Distance B C, may be known by applying to it the Semidiameter of the Earth so many Times as the Line of that Distance can receive it. The Angle A C B of the Parallax, varies in several Manners, according to the Place and Time of the Observation, and according as the heavenly Body is more or less distant from the Earth: if the heavenly Body be so far distant, that the Semidiameter A B of the Earth becomes imperceivable to the Sight, the Angle A C B is null or void, and then we say that the heavenly Body has no Parallax. Few of the heavenly Bodies have any sensible Parallax, except the Moon: It is sometimes above one Degree when taken, the Moon being at the Horiz n; but the Parallaxes of the other Planets are scarce a few Seconds: Jupiter and Saturn are so far distant from the Earth, that they have no Parallax. If we could draw exactly the Triangle A C B, we should find by carrying on a Scale of equal Parts, as we find by Calculation, that the lesser Distance B C of the Moon from the Earth, is of about 55 Diameters of the Earth, which make about 90,000 smal.l Leagues.

To measure with a Toise, or Fathom, a Piece of Ground, Fig. 58.

To Measure a Piece of Ground with a Toise, or Fathom, one must make use of a square Toise, or square Foot, the square Foot is a Square whose four Sides are a Foot or twelve Inches long.

(*Fig.* 59) A square Toise is a Square, the four Sides whereof are a Fathom, or six Feet long, containing 36 square Feet; for if the Height be divided into six equal Parts, it will contain one Foot; and if by the Points of Divisions we imagine the Lines parallel to the Base, the square Toise will be divided into six Faces; therefore the six Faces will contain six Times six square Feet, or thirty-six square Feet.

It is evident, that to have the Number of square Feet contained in the square Toise, the Number of Feet contained

tained in the square Toise, the Number of Feet contained on its Side must be multiplied by itself, *i. e.* 6 by 6, and the Product 36, is the Number of Feet contained in the square Toise.

If we have a Square whose Side would contain more or less than 6 Feet, it would be lesser, or greater, than the square Toise. But to have the Number of square Feet contained in their Square, we should be obliged to multiply the Number of Feet, contained on its Side, by itself. Suppose (*Fig.* 60.) the Side of that Square contains 4 Feet; the Square will contain 16 square Feet: but 16 is the Product of 4 multiplied by itself. If the Square has for its Side a Line which contains Fathoms, that Side must be, also, multiplied by itself, and the Product is the Number of square Fathoms contained in that Square. Suppose the Side of that Square contains 8 Fathoms, the Square will contain 64 square Fathoms, because 64 is the Product of 8 multiplied by 8.

If the Square has a Side which contains Fathoms and Feet, the Side must be multiplied, again, by itself, and the Product is the Number of square Fathoms and square Feet contained in the Square proposed. Suppose (*Fig.* 51.) the Side of the Square contains four Fathoms, two Feet, or a third of the Fathom; it is evident, that the total Square contains; First, The Square a b c d, which has 16 square Fathoms of Surface; Secondly, Two Rectangles a i l b, and a d e f, which have four Fathoms in Length, and two Feet in Breadth; Thirdly, The small Square a f g i, whose Side has two Feet in Length; but, First, To have the Square a b c d, the Side d c of four Fathoms, must be multiplied by itself, and the Product 16, is the Number of square Fathoms that Square contains. Secondly, To have one of the two equal Rectangles a i l b, four Fathoms in Length, which are equal to 24 Feet, must be also multiplied by two Feet, and the Product 48 is the Number of square Feet contained in one of the two Rectangles a i l b, or a d e f. Thirdly, To have the small Square a f g i, the Side f g of two Feet, must be multiplied by itself, and the Product 4, is the Number of square Feet contained in that Square; therefore the whole Square contains, First, The Square of four Fathoms; *i. e*, 16 square Fathoms; Secondly, Twice the Product of 4 Fathoms, or of 24 Feet multiplied by 2 Feet, which gives 48; moreover,

moreover, 48 Feet on the other Part; together 96 ſquare Feet; Secondly, The Square of two Feet, which contains 4 ſquare Feet: therefore the total Square contains in all 16 ſquare Fathoms, beſides 100 ſquare Feet, which are equal to two ſquare Fathoms; and, alſo 28 ſquare Feet. When, therefore, a Square is to be meaſured, whoſe Side contains Fathoms and Feet; Firſt, the Fathoms are to be multiplied by themſelves; thoſe Fathoms muſt be reduced into Feet, and that Number of Feet multiplied by the Feet contained in the Side, and the Product doubled. Thirdly, The Number of Feet contained in the Side, muſt be multiplied by itſelf, and that Product added to the preceding. Fourthly, The ſquare Feet are to be reduced into ſquare Fathoms, by ſearching how many Times 36 Feet, which is a ſquare Toiſe, are contained in the Number of Feet found, adding thoſe ſquare Toiſes to the preceding.

If a Rectangle is to be meaſured, the two Sides muſt be multiplied one by the other, and the Product is the Number of ſquare Fathoms, or ſquare Feet, contained in the Rectangle. If one Side has three Fathoms, and the other two, the three muſt be multiplied by two, and the Product 6, is the Number of ſquare Fathoms contained in the Rectangle. If one of the Sides has four Fathoms, and the other three, four muſt be meaſured by three, and the Product 12 is the Number of ſquare Fathoms contained in the Rectangle. If one of the Sides contains Fathoms and Feet; for Example, if one of the Sides (*Fig.* 62.) is of four Fathoms, and the other of three Fathoms two Feet, we muſt, firſt, multiply three Fathoms by four Fathoms, afterwards two Feet by four Fathoms, or 24 Feet, and we ſhall have for a Product 12 ſquare Toiſes, beſides 48 ſquare Feet, which are equal to a ſquare Toiſe, and 12 ſquare Feet. Therefore the Content of the Rectangle is 13 ſquare Toiſes, and 12 ſquare Feet. For it is viſible, that the total Rectangle is compoſed of two Rectangles, one of which contains 12 ſquare Toiſes, and the other four Toiſes in Length, or 24 Feet, or two Feet in Breadth; and therefore, that Rectangle contains 48 ſquare Feet: conſequently the whole Rectangle contains 13 ſquare Toiſes, and 12 ſquare Feet.

(*Fig.*

(*Fig*. 63.) If the two Sides of the Rectangle contain Feet; for Example, If the Side a b contains three Fathoms three Feet, and the Side a c four Fathoms four Feet, the total Rectangle will contain four Rectangles, the Rectangle a e of twelve square Fathoms, the Rectangle b e of four Fathoms in Length, or three Feet in Breadth, the Rectangle c e of three Fathoms in Length, or four Feet in Breadth, and the Rectangle d e of four Feet in Length, or three Feet in Breadth. But to have the first Rectangle, one must multiply three Fathoms by four, and the Product 12 is the Number of square Fathoms contained in the Rectangle a e: to have the Rectangle e b, four Fathoms, or 24 Feet, must be multiplied by 3, and the Product 72 square Feet, or two square Fathoms, is the Content of the Rectangle e b: to have the Rectangle e c, three Fathoms, or 18 Feet, must be multiplied by four Feet in Breadth, and the Product 72 square Feet, or two square Fathoms, is the Content of the Rectangle e c: to have the Rectangle d e, four Feet must be multiplied by 3, and the Produce 12, is the Number of square Feet contained in that Rectangle: therefore the total Rectangle contains 16 square Fathoms, and 12 square Feet. When, then, you want to measure a Rectangle, whose Sides contain Fathoms and Feet, you must, First, multiply the Fathoms by the Fathoms; Secondly, Reduce the Fathoms of one of the Sides into Feet, and multiply them by the Feet of the other Side: in that Example the Fathoms of the Side b d, must be reduced into Feet, and their Number multiplied by 3, which is the Number of Feet of the Side a b; reducing likewise the Fathoms of the Side a b, or e d into Feet, and multiplying their Number by 4, which is the Number of Feet of the Side b d, or a c; multiplying, also, the Feet of one Side, by the Feet of the other, and making up a Sum of Three Products, which will be equal to square Feet, and which being reduced into square Fathoms, the total Rectangle a d, will be had in square Fathoms, and the Surplus in square Feet, which will not be equal to a square Fathom.

To measure a Parallelogram, *Fig*. 64.

To measure a Parallelogram as a c b d, a Perpendicular must be drawn, between the two parallel Sides a d, e b, and the Base a d multiplied by the Height c d, or a f. Suppose

pose the Base a d contains four Fathoms, and the Height e d three; the Product 12, is the Number of square Fathoms which the Area, or Surface of the Parallelogram contains. For if, in lieu of the Parallelogram a e b d, we were to measure the Rectangle a f c d, the Content of that Rectangle would be 12 square Fathoms: but the Parallelogram is equal to the Rectangle; for in making the Parallelogram, we retrench from the Rectangle the Triangle a e f, and, at the same Time, add to the Remnant another Triangle b c d, equal to the preceding: therefore we must operate the known Parallelogram, for the Rectangle, and multiply the Base by the Height, or Perpendicular, of that Base: if the Base and the Height of the Parallelogram had Fathoms and Feet, the Operation should be made, likewise, on those two Lines, as for a Rectangle.

To measure a Triangle, Fig. 65.

To measure a Triangle, we must, as in the Parallelogram, draw a Perpendicular from the Vertex down on the Base, then multiply that Base by the Altitude, and take half of the Product: For if we have to measure the Parallelogram a d b e, we should multiply the Base a d by the Height; but the Triangle is but half the Parallelogram a b; therefore to have its Measure, we must only take half the Product.

To measure a Circle, Fig. 67.

To measure a Circle, one must conceive, that the Circumference is divided into a very great Number of equal Parts, and that each of them is the Base of a Triangle, which has its Vertex at the Center; the small Arch intercepted, does not differ sensibly from a right Line; the Circle will be therefore reduced into Triangles: but the Measure of a Triangle is to be found by multiplying the Base by the Height, and taking half the Product: therefore the Sum of all those Triangles, or the Surface of the Circle, will be had in multiplying the Sum of the Bases, *i. e.* the Circumference of the Circle, by the common Height of all the Triangles, which is the Radius, and taking half that Product. To have the Circumference of the Circle, we must take three times the Diameter, and its seventh Part: supposing the Diameter be of 21 Feet, the Circumference will be equal to three times 21 Feet, besides three Feet which make the seventh

ſeventh Part of 21: thus the Circumference will be of 66 Feet. Inſtead of multiplying that Circumference by the Radius, which is half of 21, you multiply it by the whole Diameter, a Quarter thereof will be the Content of the Circle. The Product of 66 by 21 is 1386; a Quarter of that Product is 346 $\frac{1}{2}$ ſquare Feet, the Content of the Circle which has 21 Feet Diameter.

To meaſure an irregular Ground, *Fig.* 68.

All Figures which are to be meaſured on the Ground, have a Relation to ſome of the preceding ones. Moſt commonly, thoſe Figures are irregular, and terminated by more than three or four Sides. Let the Figure a b c d e f g, be that which we want to meaſure: it muſt be divided into Triangles, by drawing from one of the Angles; for Example, from the Angle a, Lines to the other Angles, ſuch as a c, a d, a e, a f; thoſe Lines are drawn on the Ground, either by Means of Ropes, or by furrowing, or fixing Poles at ſome Diſtance from each other; by which Means the Figure will be divided into Triangles, ſuch as b a c, c a d, d a d, d a e, e a f, f a g. The Lines which divide the Figure muſt be conſidered as the Baſes which divide thoſe Triangles, and Perpendiculars drawn from the Vertices of thoſe Triangles to thoſe Baſes, ſuch as b a, c i, c u, e o, g p; when the Perpendiculars cannot reach thoſe Baſes, as a f in this Figure, they muſt be produced, till they can reach them; thus a f muſt be produced as far as into P and o, where they meet the Perpendicular g p, e o; ſo that one ſame Line may ſerve as a Baſe to two Triangles, to ſhorten the Operation: thus a d ſerves for a Baſe to the Triangles c a d, d a e; and a f is, alſo, common to the Triangles a e f, f a g. To draw the Perpendiculars, one muſt go with a Square along the Baſes, and applying one of the Branches on the Line along which one walks, view along the other Branch, and go forward or backward, till the viſual Ray be terminated at the Vertex of the Triangle, as is ſeen in c i. We muſt, afterwards, drawn from the Point c, to the Point i, the Line c i, and operate in the ſame Manner for the other Perpendiculars. And laſtly, all the Baſes and Perpendiculars are to be meaſured, taking Care to mark the Number of Meaſures which each of them contain, multiplying, afterwards, the Baſe of each Triangle by its Perpendicular, adding

adding only the Product, and taking half of the Sum; which will be the Content of the Figure: for it has been proved, that each Triangle is half of a Rectangle, or Parallelogram, of the same Base and Height; but in multiplying the Base of each Triangle by its Height, we have the Content of a Rectangle of the same Base and Height with the Triangle: therefore, to have the Content of a Triangle, we are only to take half the Product; and to have the Sum of all the Triangles, or the Content of the Figure, we must take half the Sum of all the Products. Supposing the Base a c contains 11 Fathoms one Foot 6 Inches, or 67 Feet 6 Inches, and the Height b 3 Fathoms 2 Feet, or 20 Feet; I multiply those two Lengths one by the other, first, the Feet by the Feet, and I have for the first Product 1340 square Feet. I multiply, afterwards, 20 Feet by 6 Inches: according to the Rule, the 20 Feet should be reduced into Inches, and multiplied afterwards by 6, which would give square Inches, to be reduced afterwards into square Feet: but to avoid being tedious in the Operation, I consider that 6 Inches are half a Foot: therefore in multiplying 20 by $\frac{1}{2}$, I must have 20 square half Feet, or 10 square Feet: thus the Product of the first Base by its Perpendicular gives 1350 square Feet. I multiply in the same Manner the second Base, supposed of 12 Fathoms two Feet four Inches, or of 74 Feet four Inches, by the Perpendicular of 31 Feet. I operate, first, on the Feet in multiplying 74 by 31, and have for first Product 2294 square Feet. I multiply afterwards 31 Feet by four Inches; but four Inches are a third of the Foot; I take, then, the third of 31, and I have $10\frac{1}{3}$ square Feet: therefore the Product of the second Base, by its Perpendicular, gives $2304\frac{1}{3}$ square Feet. I multiply the same Base by the Perpendicular e, w, of 14 Feet, first the Feet by the Feet, and I have for first Product 1036 square Feet. I multiply likewise 14 Feet by 4 Inches in taking the third of 14, and I have for second Product $4\frac{2}{3}$ square Feet; thus the Product of the same Base a d, by the Perpendicular e, w, of 14 Feet, gives $1040\frac{2}{3}$ square Feet; I multiply the Base a f of 33 Feet, by the Perpendicular e o of 18 Feet, and I have for Product 594 square Feet. Lastly, I multiply the same Base by the Perpendicular g p of 22 Feet, and the Product gives 726 square Feet. These

Multi-

Multiplications being done, I gather the particular Products into a Sum, which is of 6015 ſquare Feet: I take half of that Sum, and the Content of the Piece of Ground a b c d e f g, is of 3007 ſquare Feet $\frac{1}{2}$. To reduce thoſe ſquare Feet into ſquare Fathoms, I divide them by 36, the Number of ſquare Feet contained in the ſquare Toiſe, and the Quotient 83 is the Number of ſquare Toiſes contained in the Ground propoſed: there remains 19 $\frac{1}{2}$ ſquare Feet, which cannot be reduced, and make a little more than half a ſquare Toiſe.

1350
2304 $\frac{1}{3}$
1040 $\frac{2}{3}$
594
726
6015 ſquare Feet
3007 $\frac{1}{2}$ ſquare Feet
83 To. cont. 19 $\frac{1}{2}$ Fa.

Rule of Reductions.

If we operate by Way of Reduction, the Correctneſs of all Reductions, and the Certainty of having in great what has been done in ſmall, are founded on a Rule of an infinite Extent, that the *correſponding Sides of ſemblable Figures are proportional*, and that as many as there are of leſſer Parts in one of the Sides of a ſmall Triangle, ſo many greater there are in the correſponding Side of a great Triangle, ſemblable to it. There is a perpetual Conſequence of Equality of the three Angles to an entire Proportion in the correſponding Sides; ſince the equal Angles being impoſed on equal Arches in reſpective Circles, the Chords, which are the Sides of thoſe Triangles, cannot fail being between themſelves in the ſame Proportion of Figure to Figure; thoſe Chords correſpond to each other as faithfully as their reſpective Arches, which exhauſt on either Side the whole Circle.

Thus Man, aſſiſted by ſome Rules of Reaſoning and Experience, is contented with having on the Ground the Meaſure of a Line, and the Inclination of two others on that Line. He repeats, with Facility, the ſame Operation on the neighbouring Ground. He gives a Name to the different Vertices which terminate his different Angles. One is a Hill, the other a Chapel, the other a Steeple, or a Caſtle. Thoſe Points and firſt Meaſures marked, or coarſely drawn, either on a Slate, or a Sheet of Paper, he returns Home, and without troubling himſelf about the Rivers or Marſhes,

Marshes, Rocks, or impenetrable Thickets, which separate his Steeple from the Mill, and the Castle from the Chapel, he gives the Correctness necessary to his Figure, and, in the Tranquility of his Retreat, Judges commodiously, by a known Line, of the Value of the other. The Obstacles, which obstruct the March of a Traveller, do not stop a Geometer. He seems to have Wings to carry him above Places thought inaccessible; and, as if he had taken his Dimensions from the upper Regions, he knows and assigns the Distances better than the Inhabitants of the Country could: he takes the Map of it, joins it to another, and brings into a small Compass Provinces and Kingdoms. He draws correctly the true Representation of the Globe he inhabits.

Of Gnomonic, or Dialling.

MAN has not confined himself to take only the just Measures of his own Habitation, and of his own Works: He is not contented with exercising a kind of Magic, by exposing to View with Precision or Correctness, often without going out of his own House, the Extent of Places inaccessible to him, and even the Distance of the heavenly Bodies. He has found Means to subject to his Knowledge, and even to his Operations, Things on which he has no Power, such as Light, Shadow, and Time. He has spied the Course of the Light so far as to tell before hand, to what Point it will arrive at such and such a Place, at such a D..y, at such a Moment. The Means, which has enabled him best to follow it in its periodical Course, is to observe the Progress of the Shadow, which imitates all the Steps of the Light, and by the Help of both he has regulated Time so far, as to determine all the Moments by the Relation they have to the Point where the Sun is found at each Instant, either in its diurnal, or annual Revolution. Happy Observation, which fixes the Return, and Duration of his daily Labours, and calls, by Order, to his Memory, all past Events, and regulates his Projects for the Time to come.

The *Shadow* has most contributed towards discovering the Progress of Time by that of the Light, which it represents

presents sensibly. All opake Bodies opposed to a luminous one, intercept the Light of it. We have already taken Notice, in another Place, that what is perceived behind the opposite Surface, and to which the Name *Shadow* has been given, is not a total Privation of Light, more or less of it being reflected by the neighbouring Bodies; the *Shadow* is then but a diminished Light, and it increases, or strengthens, in Proportion as the Light decreases. We can consider the Mass of Light which extends itself from the heavenly Body, so far as to the Body opposed to it, and the Mass of Shadow which occupies the opposite Side, as a Column of Air, luminous on one Part, and shadowed on the other. Those two Parts of the Column turn on the Body interposed as on a Point of Support, and the shadowed Part, like the Arm of a Whip, makes always a Motion contrary to that of the luminous Part: so that to be capable to assign by Points and precise Measures, the Progress of the *Shadow* on one Part, it is to know the Progress of Light, and the Course of the heavenly Body which covers it on the other.

Such is the first Foundation of *Gnomonic*, or *Dialling*. This fine Art, which consists in the Representation of the Circles of the Sphere, and the Course of the *Sun*, or *Moon*, by the Projection of the Shadow opposed to them (which we call a *Dial*) has borrowed its Name from the Word *Gnomon*, which signifies equally an Index or a Dial. What can be, then, the Resemblance between that Instrument, with two Branches joined in a right Angle, and the Indication on the Course of the Shadow? They employed, at first, for that Purpose, a Quadrant, one Side thereof was fastened to the Ground, and the other, *viz.* its Point, extended to a perfect Level, to indicate the Point whither the Shadow was carried. Not contented with Projections on a Plane, the Shadow of a Point, a Pyramid, or a Ball, terminating a Support exposed to the Sun, it has been found much more proper to oppose to the Sun a long Plate, or Rod, either of Wood, or Metal, which could give long Shadows, to be traced in such a Manner, as to form an exact Representation of the Returns of the Light, by Lines, more proper than a Point, to render sensible the Position of the Shadow which contracts with that Light. Lastly, a third Manner was found of indicating the Fall

and

and Progreſs of a Ray of Light; and that was, to receive it through a Maſs of Shadow, to render the Brightneſs and Situation of the luminous Point more conſpicuous, by making it to cut on the Black round about it.

The ſecond Principle of the Art of Dialling.

The ſecond Principle, or next grand Improvement in the Art of Dialling, is owing to the following Obſervation; by Virtue whereof, the Projection of Shadows has been rendered much more eaſy and ſucceſsful. There is ſuch a Diſtance from the Earth to the Sun, that, with regard to it, our whole Globe may be conſidered as a ſingle Point; and, conſequently, the opake Body, round which we obſerve the Sun's Revolutions, may be looked upon as the Earth itſelf: whence it follows, that the regular Image of the Shadow of that Point on our oppoſite Plane, exactly repreſents the Sun's Revolutions round the Earth.

By another Conſequence of the ſame Principle, if we obſerve the Sun's diurnal Revolution round an iron Rod, placed parallel to the Axis of the Earth, this Rod becomes the ſame Thing as the Axis itſelf. It may be called the terreſtrial Axis, and the Revolution of the Shadow of our Axis, will anſwer exactly to the Revolution of the Sun. For notwithſtanding there are 1400 Leagues from the Center and Axis of the Earth, to the Point of the Style, and to the repreſentative Axis which you lay out, here, by a Line under the Sun; that Diſtance is not to be minded; both Centers making but one ſame Center, and both Axes but one ſame Line, in the remoteſt Diſtance of the Sun; and the Progreſs of the Shadow, projected by your Axis, is the Repreſentation of the Progreſs of the Sun itſelf.

The moſt able and judicious Mathematicians pretend to be fully convinced, by a Multitude of Proofs, of the diurnal and annual Revolutions of the Earth; which being but a mere Point, with regard to the whole Creation, can enjoy, ſay they, the Sight of the Univerſe, and of its different Aſpects, by Means of its Rotation, far from thinking it the immoveable Center of a Motion, whoſe Immenſity is ſurpriſing, and whoſe Rapidity is beyond all Probability. The Learned, however, by transferring to the Earth the Revolutions which the Eye attributes to the Heavens, are but ſo much the more ſenſible of the great Indulgence

of

of God to Man, in whose Favour all Appearances are so regulated, as if they all moved for his sole Benefit and Advantage; and who sees himself on his Globe, the Center of all that happens in it.

We have no Occasion, moreover, to examine, here, whether it be the Earth, or the Sun, that wheels about; because if we want to make the Shadow of a Candlestick move along a Wall, it is indifferent whether we carry the Candlestick round the Candle, or the Candle round the Candlestick; for the Effect will be the same; and it suffices, here, to follow the System with our Eyes, we want neither Observations nor Instruments to inform ourselves of the Departure or Return of the Light; but we want them to divide the Day into two equal Parts, and fix the Distance of the Rising and Setting of the Sun, with regard to that just Medium, and have, consequently, the Order of our Days; for there is nothing precisely certain to judge of the Arrival of the Sun at the Point which makes the Separation of the Eastern Hours from the Western. In that respect, we may be mistaken an Hour, at least, if not more. Some Method was therefore to be found, which might give us some Certainty of the Sun's traversing that Line which we conceive to pass from one Pole to the other, through our Zenith; since that Line cuts our Horizon in two equal Parts, and also the culminating Point of the Sun's Course above that Horizon.

The meridian Line.

The meridian Line which we suppose to be placed in the Heavens, and cut the various Points which the Sun is in from Day to Day, when he has run half his Course, was first drawn upon horizontal Planes, in a just Correspondence; and the Shadow which moves all Day round a Style, erected upon this Line, intimates, by falling thereon, that the Sun, as well as Man, has done half his Work.

It was no small Advantage to be capable of representing a Circle by a right Line; and that Representation was exact. For the meridian Line is properly the Passage of the Meridian, considered as a massive Plane, through the Plane of the Horizon; but the Section of a Plane, which traverses another Plane, is properly no other than a right Line. If you sink a round Table perpendicularly into a Surface of Mortar, the Mark left by the Table, after it has

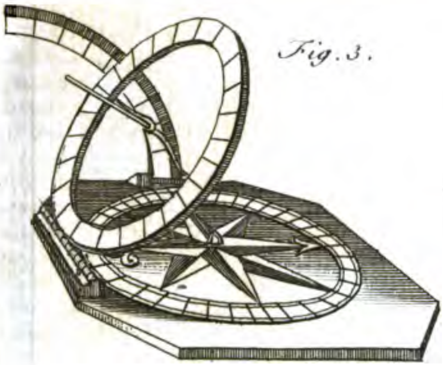
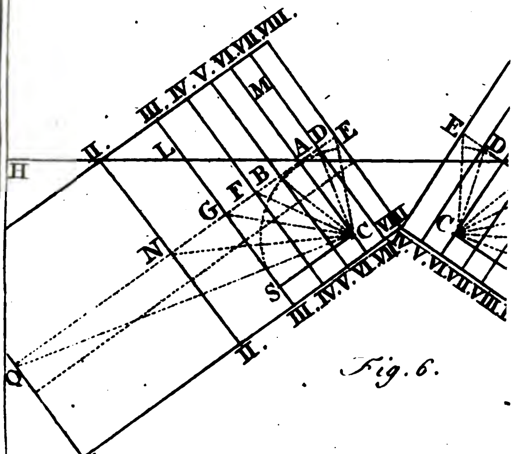
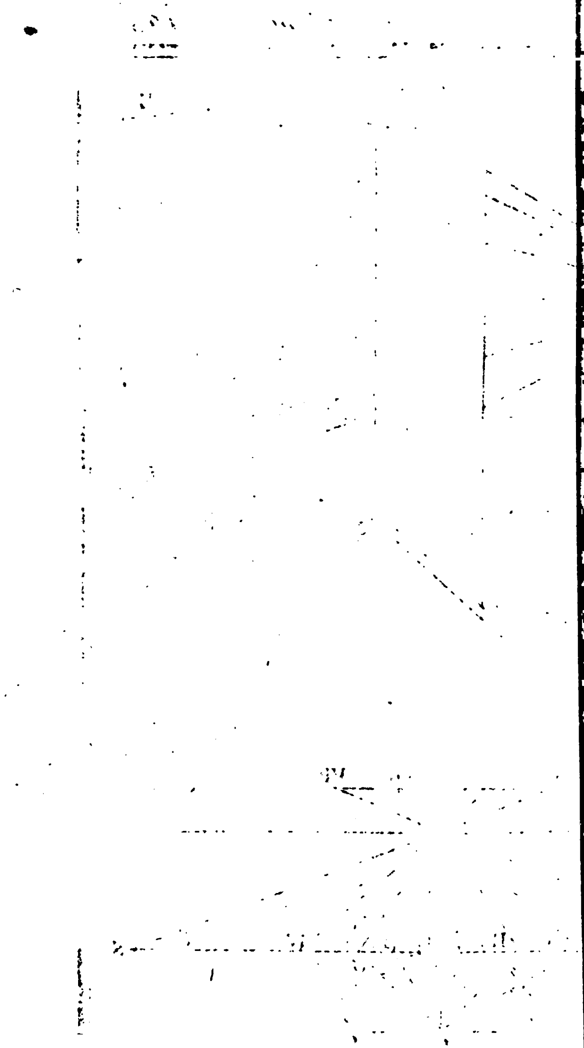


Fig. 3.



III. IV. V. VI. VII. VIII.
M
II.
L
A D E
H
F B
G
C VII
N
S
III. IV. V. VI. VII.
II.
Q
I.
E
D
C
V. VI. VII. VIII.

Fig. 6.



has been taken out, is a right Line. Should only a Nail stick out, you would see, at the Side of the Section, the Print of its Passage; because it was not in the Plane of the Table. It is highly requisite, that the Reader should understand aright, what we are now speaking of. Here is a very easy Method of finding the Intersection of the Plane of the Meridian, upon an horizontal, or * other Surface.

Plate III. *Fig.* 1.

A B, is a Level, made with a Block, and two upright Sides; it must be a little massive, that it may keep its Situation, when once fixed perpendicularly; and made of a very hard Wood, that it may not warp.

Its upper, under, and lateral Surfaces, are cut so, as to make a compleat Parallelogram: on the upper and under Surfaces of the Block, or Base; on the upper, and under Part of the Foot, Diagonals are drawn, from one Angle to the other: to have the middle Point in the Intersection C, from the Intersection of the Diagonals, traced on the Foot C, to the Intersection of the Diagonals drawn in the same Manner under the Base, a Hole is bored exactly perpendicular, and proportioned to a small iron Ball, round which the Instrument rolls without much Deviation. Upon the Base C, are erected two upright Beams, of about two Feet in Height, and distant from each other half a Foot, or somewhat more.

On the first Beam is a Plummet with its Tackle. The first upright Beam, on the Second, and on the Base, within Side, and without, reaches, on all Sides, the bisecting Line, keeping in the Middle of each Piece. Towards the End of the Base, on the bisecting Line, there is another Hole D, with an iron Ball proportioned to it, to take in and out at Pleasure: It serves with the other Ball C, to keep the Instrument in a constant Situation: It may be fixed otherwise. On the first upright Beam, and in the bisecting Line, a slight Notch E is made.

Use of it.

The first Use of this Level is to find the meridian Line, or a Line upon which the Shadow of a Body, opposite to the Sun, will fall exactly at Mid-day, on an horizontal Plane, such as the Pavement of a Church, the Floor of a Gallery, or the

* See the *Vertical* and *Horizontal Meridian*, Vol. IV. Disc. X.

Scaffolding prepared for drawing a Sun-dial againſt a Wall.

To give to the Line an exact Poſition, you muſt chuſe, if poſſible, a clear Day, about the Summer Solſtice; becauſe the Sun's Altitudes are then, nearly, in all Appearance, the ſame in the Points equally diſtant from the South; and about Nine or Ten in the Morning, place this Level, either on an horizontal Plane, or the Scaffolding built on Purpoſe to trace your Dial. After you have fixed the ſmall Ball C, in a Hole made on Purpoſe, exactly perpendicular, place the firſt upright Beam ſo, as that being on a Level between the Sun and the ſecond upright Beam, it may caſt its Shadow exactly on the whole Breadth of the Second; and the luminous Point, which will cut through the Notch E, may cut, juſt in the Middle, the biſecting Line in f. Mark out that Inſtant a firſt Point on the Scaffold, at the Extremity of the biſecting Line in A, on the Forepart of the Foot; and another Point at the other End of the biſecting Line. At the very ſame Inſtant, mark the Height of the Shadow upon the ſecond upright Beam, and the Middle, as exactly as you can, of the Point of that Light that paſſes through the Notch at E, upon the biſecting Line at F.

At any Hour of the Day, you may, if you pleaſe, expoſe the firſt upright Beam to the Sun, ſo as to cover exactly with its Shadow the whole Breadth of the other Beams; but as the Sun is continually increaſing in the Forenoon, and continually decreaſing in the Afternoon, there can be but two Inſtants when the Shadow and the Point of Light can meet at the ſame Height, and in the ſame Situation, on the Surface of the ſecond Beam, *viz.* the two Points where the Sun is at the ſame Diſtance from Noon, either before, or after; as at Nine, and Three, at half an Hour paſt Nine, and half an Hour paſt Two, at Ten, and at Two, and ſo at any other Hours, with their Quarters, and Halves, or other correſponding Minutes.

Suppoſe your firſt Obſervation to be made at Ten in the Forenoon, *i. e.* two Hours before Mid-day, you muſt get ready for the Second, a little before Two in the Afternoon: turn your Inſtrument round the iron Pin C, towards the Sun, which here paſſed from Eaſt to Weſt; and when, in feeling the Poſition of the Level, you will ſee the Sun cutting

ting by Degrees the Shadow of the first Beam, and the luminous Point of the Notch exactly at the Points marked in the Morning, upon the other Beam; you are then, undoubtedly, at the same Distance from Noon, and the Sun is at the same Height above your Horizon: mark therefore immediately upon the Scaffold, the two Extremities of the bisecting Line, which crosses the Base.

Take off then the Level, you have the two Points for the Morning, and the two for the Afternoon. Join them by two Lines crossing each other: then (by Problem the 70th) draw a Line to pass at an equal Distance from those Points. If the Operation be right, it will (by the 66th) reach the Point of Interfection, and this Line is the meridian Line sought. For a greater, repeat the Operation another Day, and instead of the Hours of Ten and Two, make Choice of Nine and Three, or some other Points equally distant from Mid-day. If your meridian Lines, taken separately, are found confounded into one, there is room to suppose that you have succeeded. But if you have two meridian Lines, instead of one, either the Operations, or Instrument must be rectified.

After you are very sure of a Meridian Line on the Horizon, or Scaffolding, you may transfer it on a Wall made perpendicular, which is called a vertical Plane, by drawing upon it a Line perpendicular to that which you have drawn upon the Scaffold. For, as this is the Section of the Plane of the Meridian on the Horizon, the other is the Section of the same Plane on the vertical perpendicular to the Horizon. However, it is not always necessary to draw this Line upon the Wall.

What we shall add to this Operation, will give you the Hour of Mid-day, with the rest of the Hours on all Sorts of Planes. It suffices to prolong the meridian Line of your Scaffold, so as to touch the Wall by a Point which you may mark upon it.

If you have no other Design than to have a fixed meridian Line, to set your Pendulums, or Watch, after you have traced it on an horizontal Plane, and transferred it, if wanted, on a vertical, you must erect upon it a Style, either upright, or oblique, to cast on that Line the Shadow of its Vertex, the Moment the Sun enters the Meridian, which makes the exact Partition of our Horizon. The

Exactness of the Position of that Vertex consists in its being in the Plane of the Meridian; for otherwise, the Shadow of that Vertex being not itself in the Plane of the meridian Circle, would not fall, at Mid-day, on the meridian Line, which is the Intersection of the meridian Circle on the vertical Wall. On the contrary, the Vertex of your Style, and its Shadow, or the luminous Ray which pierces it, will be in the Plane of the meridian Circle, if that Vertex be precisely brought between the meridian Line, which is on the vertical Plane, and a Parallel in the meridian Plane; which Line is easily found: it is a String hung in such a Manner, as falling perpendicularly on the horizontal meridian Line of the Scaffold, it is found parallel to the meridian Line drawn on the vertical Surface. Whatever is between these two Lines, is in the Plane of the meridian Circle: therefore the Vertex of your Style is infallibly found in it. By looking carefully, you find it hidden, or cut between the String and the meridian Line, drawn on the vertical Plane; that Line being quite covered by the String, you are sure that your Style is rightly fixed.

You are sensible, that the Sun describes every Day new Circles parallel to the Equator, from which it declines for three Months successively, 23 Degrees thirty Minutes from the Meridian; that it returns towards the Equator again, during three other Months successively, and performs the same Course during the following six Months in the other Hemisphere. It never returns therefore two Days together at the same Point of the Meridian; therefore the Shadow of the Vertex of the Style, shifts its Place in Proportion, on the meridian Line; but, at Mid-day, it falls, always, on the Points of that meridian Line, higher, or lower, it never quits it at that Hour; because the Sun, to which the Shadow is always opposite, is found at Mid day in the Plane of that Circle.

When that Shadow arrives on the Meridian, it gives you Notice, that the Sun is half Way his Course over your Horizon; but it does still more; for as it changes Place from Day to Day, on that Line, it points out to you also, the various Declinations of the Sun from the Equator.

The different Points on which the Shadow falls, and which are seen expressed upon it, by the Figures of the twelve

twelve Signs of the Zodiac, or by the Names of the Months, or of the Days, when the Sun enters those Signs, and passes over such or such Degrees, are sufficient to express the Sun's Entrance in the twelve Signs; the two last, or most distant from the Equator, are the Tropics of *Cancer*, and *Capricorn*; the five other Points receive the Sun twice a Year, once in its Ascent, and once in its Descent. They serve to the Position of two Signs; since the Point of the meridian Circle, where the Sun arrives when he passes under the Parts of *Aries*, is the same with that where he reaches our Meridian, when he enters *Libra*. The Point of the Meridian, under which the Sun passes, when he quits *Gemini*, to enter *Cancer*, is in the same Declination, or Distance of the Equator, with that where he repasses under our Meridian, when he quits *Cancer* to enter *Leo*; and so of the rest.

The Sun, indeed, does not make these different Progresses on the Meridian; for his Course is entirely through the oblique Circle, that extends to 23 Degrees 30 Minutes on each Side the Equator. Therefore in his different Positions in the Ecliptic, he is brought, by its daily Revolution, to different Points of the Meridian; and the Distribution of those Points, in the Content of twice 23 Degrees 30 Minutes of the Meridian, ought not to be by the Divisions of six equal Parts of an Arch of 47 Degrees; but by a Division that represents on that Arch the Sun's Situation in the twelve Houses of the Zodiac.

In order to find the Arch of 47 Degrees of the Meridian, which include the Declinations, we will chuse a meridian Line, drawn on a polar Plane parallel to the Axis, and consequently, inclined 47 Degrees on our Horizon H O, and exactly opposite to the South. On this meridian Line, or on the Line M, which represents it, raise at right Angles the Perpendicular E q, which represents the Equator, or rather the Intersection of the equinoctial Circle on that Plane: from the Point where that Line touches the meridian Line, take at any Time, with a Compass, the Distance, or perpendicular Height of the Vertex of the Style S; then, from the Point S, carried at the same Distance from the meridian Line, upon the equinoctial Line E q, and with the same Opening of the Compass, draw the Arch of

Fig. 2.

the Meridian E C. Upon this Arch measure 23 Degrees and an half, on each Side, to have the Declinations of the Sun, from its Entrance into *Capricorn*, to its Arrival at *Cancer*, and it is from that Point C, that the Sun takes up six Months, to arrive at E, and the other six Months from E into C. The Circle which the Sun runs through, and divides into equal Parts, extends itself obliquely to the Equator, so that the two Points of that Circle, the most declining from the Equator, pass, in the diurnal Revolution of the Sphere, under the Points E and C of the Meridian. The Sun therefore arrives every Day in some of the Points of this Arch of 47 Degrees of the Meridian, according to its various Progresses through the 12 different Asterisms, which border its oblique Circle, its annual Orbit.

To give an Idea of the various Positions of the Sun, when he will come, twice a Year, under all the Points of that Arch of the Meridian, which the Sun is to go through twice a Year, excepting the two most declining Points, which he glances upon but once, it suffices to draw, from a Point taken for the Center, at an equal Distance from E and C, the Circle B, E, L, C, and to divide it into 12 equal Parts: if the Points of the Division found two and two, equally distant from the Equator, be joined by surd or pointed Lines, and parallel to the Equator; these parallel Lines will divide the Arch C E into Points more distanced towards the Equator, and nearer towards the Tropics. These are the Points of the Meridian through which the Sun passes and repasses, without quitting its Ecliptic, and following an uniform Course: if then, the Sun shines in *Cancer* at E, the Shadow of the Style S will fall upon the meridian Line on the 21st of *June*; if it shines in B, in *Aries*, or in *Libra* L, the Shadow will fall on E q, on the 21st of *March*, or the 23d of *September*. If the Ray comes from *Capricorn* C, into S, the Shade will carry it on the meridian Line, on the 22d of *December* The rest is easily understood. The small Circle which we have described, and extended from the Point of the Winter Solstice to that of the Summer Solstice, takes in the whole Interval, which traverses the Ecliptic. Like the Ecliptic, it is divided into 12 Houses. Whether the Sun occupies the upper or lower Part of the parallel Lines we have drawn

from

from Point to Point, it produces the ſame Effect. The Sun, in its diurnal Revolution, equally aſcends, and paſſes through the ſame Points of the meridian Circle.

We have, therefore, by that Means, a faithful Repreſentation of the different Poſitions of the Sun in that Arch of the Meridian that includes all its Declinations: conſequently, we have alſo the Declinations of the Shadow that anſwer to them, on the meridian Line: and if this meridian Line, inſtead of being, as it is here, on a Plane which makes a right Angle * with the Equator, ſhould be drawn on another Plane, it would have the ſame Effect. The Lines drawn from the Arch C E, through S, will go, according to their Diſtraction and Extenſion, to mark on the meridian Line their Point of Fall, or the Entrance of the Sun in each Sign.

Aſtronomers have carried the Exactneſs of their Calculations ſo far, as to mark on the meridian Line, and even along the reſt of the Hour lines, the Poſition of the Shadow that anſwers every Day to the Sun's actual Situation in the Zodiac: and thus a Sun-dial becomes a perpetual Almanack.

The Geometrician conſiders himſelf as in the Vertex of the Style; and from that Point, which the Sun's great Diſtance allows him to confound with the Center of the Earth, he obſerves the Rays of the Sun as they paſs from one Parallel to another. He ſees thoſe Rays, in the equinoctial Days, fall perpendicularly on the Axis, which paſſes through the central Point which he occupies. He ſees them coming towards him obliquely, and under different Obliquities, in Proportion as the Sun is found on more declining Parallels. He makes of thoſe Lines, which every Day ſhine variouſly on him, Cones, whereof the Geometrician occupies the Vertex, and whoſe Baſes he ſees fixed at a great Diſtance from Parallel to Parallel. He calculates the Differences of all theſe conical Lines, to draw afterwards, by exact Points, the Degree of the Sun's Courſe, the Sign, the Declination, the Month, and Day, that concur with the actual Hour.

This Work is no ſmall Credit to us; but the Knowledge we have of the current Month, and of the Day that lights

* See Vol. IV. Dialogue X.

us, renders us, most commonly, very little attentive to this Multiplicity of Points and Lines, which express in the Dials no more than what we know already. We do not know the Hour; and, to be informed of it, we approach a Dial; let us learn, then, how the Distribution of the Hours is made upon it. For that Purpose, we apply ourselves to the Sun-dial.

Sun-Dials. Instead of using the Shadow of the Vertex of a Style, or a radiant Point received thro' the Shadow, by Means of a Hole made thro' a Wall, or a Board, let us make use of an iron Rod, to represent the Earth's Axis, for a Reason which I hope you will approve.

The whole Length of this representative Axis being wholly in the Place of the meridian Circle, cuts, at Midday, the opposite Surface, by a Line of Shadow extending along the meridian Line. This Projection of the Shadow of the Axis does not differ, at that Instant, from the Intersection of the Plane of our Meridian on the Surface offered. 'Tis on either Side a right Line, and the same. A small Ball may be fixed to any Point of this Axis, whose Shadow will shift Place every Day, as the Sun does, but without quitting the Line at Mid-day. Notwithstanding, therefore, the Diversity of the Sun's Declinations, this Line of Shadow will constantly mark, every Day, the Hour of 12 at Noon, by lying along the Line of Intersection of the Plane of the Meridian, on the opposite Surface. Now all the horary Circles, which must be particularly observed, which the Sun reaches from one Hour to another, are so many Meridians for different Horizons. All these Meridians pass through the same Axis, whether the terrestrial, or its Representative; which is the same Thing, since the Axis of the Earth, and that of the Dial, are confounded with regard to the Sun: this Axis, therefore, is in the Plane of each of these Meridians: whence it follows, that the Projection of the Shadow of this Axis, by displacing itself fifteen Degrees in an Hour, as the Sun does, will perfectly represent the successive Intersections of each horary Plane, on the Surface of the Dial, by a Line, which is the same all the Year. It is, indeed, the same every Day, at the same Hour, because the Sun comes every Day

to

to it, notwithstanding his Declinations, returning every Day at the same Hours, though sometimes higher, and sometimes lower, yet always in the Plane of the same Meridian. To have the Intersections of the Planes of the horary Circles disposed, at every 15 Degrees on the Equator, is then the same Thing as to have the Projection of the Shadows of the Axis, which make Part of all these Planes: reciprocally, to have the Projections of the Shadow of this Axis, which traverses all those Planes from one End to the other, is to have the Intersection of all the horary Planes on the Plane of the Dial. When you have drawn these Lines, fix your iron Axis parallel to the Axis of the Earth, then your Dial is finished. These Intersections of twelve or twenty-four meridian Planes on a Surface, are as easily had, as the Division of a Circle into 12 or 24 equal Parts. Therefore it is also very easy to have the Projections of the Shadow, and of the Axis, that Shadow being inseparable from the Intersections.

Equinoctial Sun-dial.

Sun-dials are distinguished by Names, according to the Planes of their Surfaces: Let us begin with one in a Plane parallel to the Equator, which we call an Equinoctial-dial. For that Purpose, draw a meridian Line horizontally on whatever Support you think proper to chuse: raise upon it a Copper Plate, or of any other Metal, or a Slate, till it is parallel to the Equator, and after you have drawn on each Side the Plate a Circle, divided into 24 equal Parts, or 48 if you would have the half Hours; drive an upright Style perpendicularly quite through the Plate, and draw Lines from the Center to the Points of Division: if you make the south Line answer to your meridian Line, and the equinoctial Plate be raised so as to make an Angle of 41 Degrees with the Support, for the Horizon of *Paris*, your Dial will be finished, and mark the Hour all the Year.

All Triangles (by *Prop.* 133.) are equivalent to two right Angles; but your Equator, its Axis, and the Horizon, or the Surface of the Support, which is parallel to the Horizon, make, together, a Triangle; you ought, therefore, to find the Value of 180 Degrees in the three Angles. But, by the Construction we have seen above,

 the

the Axis makes a right Angle with the Dial, which is here the ſame Thing. The two remaining Angles, with the Equator, therefore, are together equivalent to 90 Degrees. Now your Dial, and equinoctial Plate, making an Angle of 41 Degrees with the Horizon, there remain 49 Degrees for the Angle which the Axis makes with the Horizon; therefore your Dial is at the right Height of the Pole which ſuits with *Paris*. Beſides, your Equator being by the ſame Conſtruction expoſed to the true South, ſo that the Hour Line of 12 cuts in it the meridian Line in Length; the Line of 6 Hours, which cuts the meridian Line at right Angles, on the regular Planes, draws here towards the true Eaſt, and true Weſt; your repreſentative Equator will therefore become parallel, every Way, to the real Equator, and one is confounded with the other: conſequently the Sun will be ſix Months ſucceſſively on your Equinoctial, and ſhine upon it from the 21ſt of *March* to the 23d of *September*; the next Day following, he will paſs to the meridional Part, and enlighten the under Surface during the Autumn and Winter; and the Axis caſting its Shadow upon it, as the Sun does its Light, that Shadow will mark every 15 Degrees, a new Hour. The inferior will furniſh but 12 Hours about the Equinox, and about 8 at the Winter Solſtice; becauſe it can mark no longer than the Sun is on our Horizon; whereas the ſuperior Part will, for the ſame Reaſon, furniſh 12 Hours, after the Equinox of the Points, and 16 at the Summer Solſtice; that being the Time which the Sun remains on our Horizon in the Summer.

Fig. 3. Such is the Conſtruction of the portable Equinoctial-dial. It is made up of a Compaſs-box, a moveable equinoctial Circle, a Quarter of a Circle moveable alſo, and a Style, which, by Means of a Spring, may be raiſed above or below the Equator. The Compaſs-box helps us to find the meridian Line; the Quarter of a Circle ſerves to raiſe the moveable Equator to the Complement of the Altitude of the Pole for the Place; and, laſtly, the Style with a Spring is of Uſe, during ſix Months, on the upper Side, and as long on the under.

The

The horizontal Dial, which is very much in Use, because it serves throughout the whole Year, is drawn on a Plate of Metal, or a Table of Stone. Draw on the Plate the Line XII, D, which is taken for the meridian Line, and which will become such when laid flat on another meridian Line drawn before. If from a Point of the meridian Line, as D, you raise obliquely a Line, or an iron Rod P D, which shall make with the horizontal Surface an Angle of 49 Degrees for *Paris*, that Line will imitate the Axis of the Earth. Upon this Axis, at the Point g, taken at any Time, raise a Perpendicular, which will meet the meridian Line and horizontal Surface at the Point which will be called XII. The Angle of the Axis, with the meridian Line, and the right Angle of the Line g XII. with the Axis, are to be measured on the Plate on one Side the meridian Line. These Lines are afterwards to be realized in Iron, and raised up above the Plate in the Plane of the meridian Circle. These three Lines may be represented by a Triangle of Tin, of the same Measure, and will rise perpendicularly over the meridian Line; the raised Back of this Triangle will serve for an Axis.

The horizontal Sun-dial.

Fig. 4.

The Line g XII being at right Angles with the Axis P D, and this Axis making an Angle of 49 Degrees with the meridian Line or Surface of the Dial, both Sums make up the 139; there remains the Sum of 41 Degrees to compleat the 180, which is the Value of the whole Triangle, and the Angle of the Equator, with the Horizon of *Paris*. The Line g XII perpendicular to the Axis, and inclined 41 Degrees to the Horizon, according to the Complement of Latitude, is therefore, in this Place, the true Radius of the Equator; if we seek after the Intersection of the equinoctial Circle, prolonged on the Horizon, we shall find it at the Foot of the Radius g XII, and in the indefinite Line O S, which crosses the meridian Plane perpendicularly; since the Line of the Equator cuts the Plane of the Meridian at right Angles. Instead of fixing the Axis, or back Part of the triangular Style, on a Line of Support, which imitates the Inclination or Radius of the Equator, that Support is made perpendicular to the Plane of the

Dial, which is a Thing of little Consequence in regard to the Use of the Dial.

Let us suppose, at present, the rest of the Hours to be so many meridian Circles, that pass through the Equator at the Interval of 15 Degrees, luminous as far as the Axis which divides them all, but shadow'd on the other Side of the Axis, which is opposite to the Sun. To find in which Points of O S those Lines will terminate, let us place a Semi-equator, such as C 12, flat on the Horizon, by opening the Compass to the Length of the Radius g XII, and let us divide this Circle into 12 Hours, or 24, to have the half Hours. Let us draw the Line 12 straight to the meridian Line XII D, the horary Lines, or shadow'd Planes, 1, 2, 3, 4, 5, being produced, will meet on the Intersection of the real Equator in Points, which you are to mark I, II, III, IV, V; in the same manner the Planes 11, 10, 9, 8, and 7 pointed on the Semi-Circle every 15 Degrees, and produced as far as to the equinoctial Intersection O S, will meet in Points, to be marked XI, X, IX, VIII VII, with the Halves. These must be divided on the Semi-Circle where they are equal, and not on the straight Line O S, where (by *Prop.* 71.) they become much longer, and farther distant from each other, in Proportion as they fall more obliquely thereon.

Thus a thin triangular Plate, perpendicularly fixed on the meridian Line, with its Vertex in g, or only a simple Style placed perpendicularly, or so as to have its Vertex at the Height, and in the Situation of g, will point out the Hours, by the Shadow only moving from one Hour-Line to another, through the Equinoctial O S; because that Vertex is in the Axis where all the horary Circles cut each other, because these Points of Divisions on the Equinoctial O S are in the Planes of each horary Circle where the Sun is found. It is evident, that if the Sun is in one of the Planes, the Point g of the Axis, which is part of that Plane, and the horary Point which answers to it in the same Plane, are all exactly opposite. The Point g hides the Sun from the horary Point, and becomes the Point of Division between the Light and the Shadow.

But, instead of the Shadow of a Point, let us take the Shadow of an Axis lengthened at pleasure; we shall find

in it the Advantage of a Line of Shadow different from all other, and also a new Proof of the Truth of our horary Divisions.

The Axis P D, being raised over the horizontal Plane at the Point D, stands in the Air in the Plane of the Meridian; and the Shadow of the Axis is so much a Part of that Plane, that it represents it, as soon as the Sun comes there. This Edge or Point of Shadow is therefore a kind of moveable Style, that turns round the Axis opposite to the Sun, and when the Sun is in another horary Circle, the Point of Shadow shews the Plane of the Circle, by keeping in the Part opposite to the Sun. To know justly whither that Point of Light will carry itself in all Cases, we must have recourse to our half Equator, which we have placed and divided on the Horizon. Let us consider this half Equator C 12, not as a mere lineary Semi-circle, but as if it was made of solid Matter. We will take it by the Point C, and keeping it upright, without putting the Line 12 from the meridian Line XII, raise it up by the Point C 1, C 12, and keeping the Point 12, we will bring the Point C to g; then, if the Sun be in our Meridian over C, the moveable Point of Shadow, keeping in the same Plane with the Sun, will fall upon the XII of the Horizon, as well as upon the 12 of the Equator. If the Sun moves 15 Degrees more Westerly, the Shadow of the Axis, as a moveable Style, will lie along 1 in the Semi-circle, and arrive into I in the Horizontal Dial. Lastly, this Point of Shadow will proceed, and move from one Line to the other in the half Equator every 15 Degrees, and extend itself in the same Direction, so as to meet the Points of the Horizontal Plane, so far as where they are prolonged and stopt. But this Point of Shadow, in turning round the Axis like a moveable Style, proceeds from every Point of the Axis; it proceeds therefore from the Point D, as well as from any other. All the horary Circles, therefore, which are represented by it alternately, interfect each other at the Point D, and this Point, whence the Axis issues from the Dial, becomes the Center of the Dial, and of the horary Lines. We have, therefore, nothing more left to do, than to draw Lines from the Point D to the Points of the Hours, VII, &c. and in Proportion

as

as the Sun ſhall ſhine on one Side of the Axis, the Shadow will of Neceſſity fall on the oppoſite Lines behind the Axis.

When the Point of Shadow becomes parallel to the Line C 6 of the half Equator, it will be parallel to the equinoctial Interſection O S; but as the Shadow cannot meet with that Line, it will be neceſſary to ſearch another Line for the ſixth Hour.

Since the Point of Shadow, that revolves round the Axis and the Point D, is at Six o' Clock perpendicular to our meridian Circle, and parallel to the Interſection of the Equator, there is nothing more to be done, but to draw through the Center D, where the horary Point is to paſs, a Line parallel to O S; this Parallel will be the Interſection of the horary Point of ſix on the Horizon: Since that Point, repreſenting the Plane of the Circle of ſix Hours, muſt cut the Horizon with the Axis, which leans on the Middle of that Plane. 'Tis therefore at the Foot of the Axis, at the Meeting of all the horary Lines, at the Center of the Dial, and at right Angles with the Meridian, that the horary Line of Six muſt be drawn.

If the Sun be on the Horizon by Six in the Morning, or after Six in the Evening, to have the horary Lines of Four and Five in the Morning, you need only prolong, on the other Side of the Line of Six, the Lines of IV and V in the Evening; and to have the horary Lines of VII and VIII in the Evening, prolong, beyond the Line of Six, thoſe which give VII and VIII in the Morning. The Reaſon of this Practice is plain and obvious. If after the Sun has over-run every 15 Degrees, twelve horary Circles be found ſtill on our Horizon, the new Circles which it over-runs are the ſame with preceding ones, taken only in a contrary Senſe. The Plane of each horary Circle, at which the Sun arrives, is half way luminous, and half ſhadowed; it is luminous at the Axis, and half ſhadowed beyond the Axis; ſo the Sun, at Six in the Morning, caſts the Shadow of the Axis towards the Weſt: But twelve Hours after, being arrived in the ſame Circle, he enlightens that Part where the Shadow was at Six in the Morning, and caſts the Shadow of the Axis towards the Eaſt; and thus of the other Hours. But that can go no farther than

than Four and Five of the Morning, or Seven and Eight of the Evening in Summer; since the Sun, at the other Hours, is always under the Horizon.

To make a vertical Dial against a Wall, or on a Surface exactly opposite to the South, you are to drive an Axis into the Wall, on the meridian Line you must have previously drawn upon it, so as to make with the vertical Wall an Angle of Supplement equal to the Height of the Pole, *viz.* of 41 Degrees for *Paris*. These Measures are first taken on Paper, by raising the Line D P to the Angle D P of 41 Degrees on the meridian Line D C. Raise afterwards upon the Axis D P, at any Point taken at pleasure, as g, a Perpendicular, which will fall on the meridian Line on a Point, which you are to mark XII. This Line g XII will therefore make with the Plane of the Wall an Angle of 49 Degrees, which is the Distance of the Equator from the Zenith, always equal to the Height of the Pole on the Horizon. By dividing the right Angle, formed by the vertical Wall and the Horizon, into two acute Angles, one of 49 Degrees on the Side of the Wall, the other of 41 on the Side of the Horizon, the Line g XII will be parallel to the Equator, and may be taken for its Radius: of the Height of that Equinoctial Ray draw, as you have done for the Horizontal Dial, a Semi-equator, a Semi-circle C 12; divide it into twelve equal Parts, we will call or mark the first and last 6; that in the Middle will be 12; join the Line C 12 with the meridian Line XII, and carry the Lines of the other Divisions, by prolonging them, till they meet with the Line O S, which is perpendicular to the meridian Line in XII, and passing by the Foot of the equinoctial Radius g XII. If you conceive the Axis as coming out of the Wall, and by lifting up your lineal Semi-equator you bring its Center C to the Point of the Axis g, you will then see, that the Line O S is the Intersection of the Equator on the Plane of the Wall. All the horary Circles, except that of Six o' Clock, carry their shadowed Points from the Axis to the Equinoctial Intersection O S. Therefore the Lines drawn from the Divisions of the Intersection O S, ought all to meet at the Point D, where the Axis is drove into the Wall. All the horary Planes, which have those Lines for Sections, together

ther with a Line drawn from the Point C, and parallel to the Section O S, represent the Point of the moveable Shadow, which, by revolving round the Axis, cuts the Meridian at right Angles. You will readily perceive this to be the horary Line of Six for Morning and Evening. When these Lines with the Axis, without changing the Angle of 41 Degrees, are transferred on the vertical South Wall, the Dial is finished.

Since this Wall has its two Extremities towards the true East and West; the Sun, at Six in the Morning, and Six in the Evening, directs its Rays parallel to it, and penetrates its Thickness; for which Reason, the vertical South Dial cannot mark the Hours, till immediately after Six in the Morning, when the Sun begins to shine thereon, and a Minute before Six in the Evening, when he leaves it. The other Hours, which it gives before Six in the Morning, and after Six in the Evening, may be drawn by carrying on the Northern Surface of the Wall the Measures abovementioned; and prolonging with apparent Dashes the Lines of IV and V for the Morning; then of VII and VIII for the Evening.

Northern Dial.

Eastern Dial.

Let us change the Plane, and take a Wall, one Side whereof faces exactly the East, and the other the West. This Wall is in the Plane of our Meridian; the meridian horary Circle which passes through our Zenith, and the Axis that lies on the Plane of that Circle, are therefore parallel to this Wall, or lie in its Thickness: The Axis of the World makes no Angle with the Plane of this Wall. If the Axis does not run through the Surface of this Wall, the Dial we intend to draw on it has no Center, or common Point of Intersection for the horary Lines. How then shall we have the Shadow of the Axis, and that moveable one which answers to the Sun, changing Circles every 15 Degrees, whilst it moves round the Axis. This must be done by raising on the Dial a thin Plate of Iron, in the Form of a long Square, which by its upper Line imitates the Position of the Axis; or by driving into the Wall a Supporter, to bear up by one of its Extremities an Iron Rod parallel to the Wall and the Axis of the World. The Shadow turning round the Axis, and being constantly in Opposition to the Sun, will fall straight

on

on the Wall at Six in the Morning, when the Sun shines full upon it, and will sink lower as the Sun rises higher. The shadow of this Axis will be projected, six Hours after, perpendicularly to the Projection of six Hours, and become parallel to the Wall; therefore it will be impossible to mark the Hour of 12 at Noon, unless we take that very Circumstance of the Shadow's quitting the Dial for that Hour. Such a Style, or Iron Rod, placed in the same Manner on the other Side of the Wall, will begin the next Instant to project its Shadow. All these Projections are necessarily parallel among themselves: But what are the Distances to be assigned to each? We shall be directed here likewise by the meeting of the horary Lines of a Semi-Equator on a Line that represents the Interfection of the real Equator on the Plane.

Draw the horizontal Line H O, and on the Point A, taken at any Time in that Line parallel to the Horizon, raise the Angle M A L equal to the Height of the Pole for the Place where you are; we will continue to take, for Example, 48 Degrees, 50 Minutes, or only 49 Degrees, which is the Altitude of the Pole for *Paris*: if, then, through the Point A you draw the Line E Q, so as to make with the horizontal Line M O an Angle equal to the Elevation of the Equator, or a right Angle with A M, parallel to the Axis, the three Lines E A Q, M A C, O A H, will represent the Intersections of the Equator, of the Circle of Six, and of the Horizon with the Meridian, which is the Wall. Fig. 6.

In our Account of the preceding Dials, we have taken no Notice of the Substylar-line, which is a Line that passes through the Foot of a Style placed upright and perpendicular to the Plane of the Dial, either to cast a Shadow with its Point, or to support the Axis. This Substylar-line was hitherto no other than the meridian Line. Here the Meridian, and the meridian Line being in the Plane of the Wall, the Substylar-line will be the Line of Six. 'Tis on the Point A, and on a Line inclined of 49 Degrees on the Horizontal, that you must raise a Blade, in the Form of a Parallelogram, to cast a Shadow with its upper Point; or an upright Style to cast a Shadow with its Vertex, or an upright Style, supporting an Iron Rod parallel to the Axis

of the World. The Reason for making Choice of the Point A for the Foot of the Style, and the Line M A C for the Sub-stylar, is founded on the Sun's Aspect.

At Six o' Clock, when the Sun, gliding parallel with the Plane of the Equator, makes a right Angle with our Meridian, he makes, also, a right Angle with the Eastern Wall: That Ray therefore falls perpendicularly on the upright Style, or Blade perpendicular to the Plane, both being, at that Instant, without Shadow. An Iron Rod fixt at the Top of the Style, so as to be parallel to the Axis of the World, will cast its Shadow at Six on the Line M A C, placed horizontally like that Axis, this Shadow, being perpendicular to the Plane, will be the shortest that can fall upon it; by turning afterwards, like a moveable Blade, round the representative Axis, it will grow longer, as it becomes more oblique, and fall along the Plane, ending upon it, by a Line always parallel to the preceding Projection of the Shadow.

To find out the Height of the Supporter which carries a Rod parallel to the Axis, or the Height either of the Blade or Style; and to determine the Spaces of the Hours, we will make Use again of a Portion of the Equator, by drawing it on the Plane on the Surface of the Dial.

Take the Length A C, then with that Length, as a Radius, and with C, as a Center, describe the Arch A S of 90 Degrees. Divide this Quadrant of the Equator into six equal Parts, and through the Points of Division draw on the equinoctial Section E Q, the Lines C B, C F, C G, C N, C Q; then through B, F, G, N, Q, draw Lines parallel to M C, or, which is the same, perpendicular to the Equinoctial E Q, they will be so many horary Lines from Six in the Morning to Eleven.

Western Dial.

By much the same Process we shall have the horary Lines on the West Surface; nay, and if you draw first your East Dial on Paper, and oil it, then view it on the Back-side, it will represent to you the West Dial. Only the XI will be changed to I in the Afternoon, the X to II. and so of the others.

The Hours before Six in the Morning, and after Six in the Evening, are found by prolonging the Arch described, and taking in the Continuation of the Arch, so many

times

times 15 Degrees as the Sun gives Hours before Six in the Morning, or after Six in the Evening; you will carry two Lines from C to the two Divisions D and E, and through those Divisions so many Parallels to M A C.

Let us now suppose the Arch C P A S to be raised or erected perpendicularly to the Plane of the Dial, the Center C to be erect, and A the Point of Contact on the Section E Q. We will pierce that Center with an End of the Axis, or an Iron Rod parallel to M A C, the Shadow of this Axis turning round as a Plate, will be eight Hours in running over the Arch P A S. The Parallels which pass through the Divisions of P A S, being prolonged so far as into the Section of the Equator E Q, on the Plane of the Dial, are the necessary Intersections or diverse Falls, which the Shadow, rolling under the Iron Axis opposite to the Sun, will make. We have made use of an Iron Axis, fixed at the End of the Style, in order to make Things more obvious. But an upright Style only will mark the Hour by the Shadow of its upper End; or a thin Iron Plate will have the same Effect with the Shadow of its upper Edge. Only observe, that the Supporter of the Axis, the upright Style, or the Parallelogram, must be of the Height A C, the Radius of the Equator, by which the whole Work is regulated.

Polar-dial.

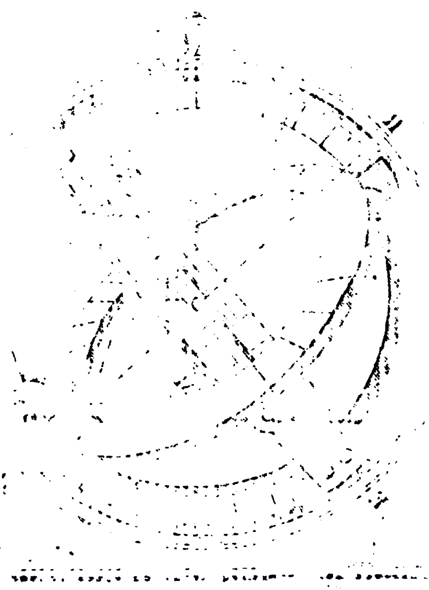
The Polar-dial, that is to say, a Dial whose Surface is parallel to the Axis, by prolonging its two Extremities towards the two Poles, and its facing the South, has likewise its Projects of Shadow in parallel Lines. It has no Center, because the Axis does not run through it; the Meridian falls directly upon it, and divides it by a straight Line, which is the meridian Line. If any thing be raised in it to cast a Shadow, it must be in the Plane of the Meridian, and so as to cast into it, that very Instant, the shortest Shadow, since (by *Prop.* 71.), it is perpendicular to the Plane, the Sun passing directly over; after which, that Shadow will increase more and more in Length, on each Side, in Proportion to its Obliquity, and will cease marking the Hour at Six in the Evening, to begin again after Six the next Morning; because the Shadow, projected six Hours before Mid-Day, or six Hours after, is parallel to the Plane, and therefore meets

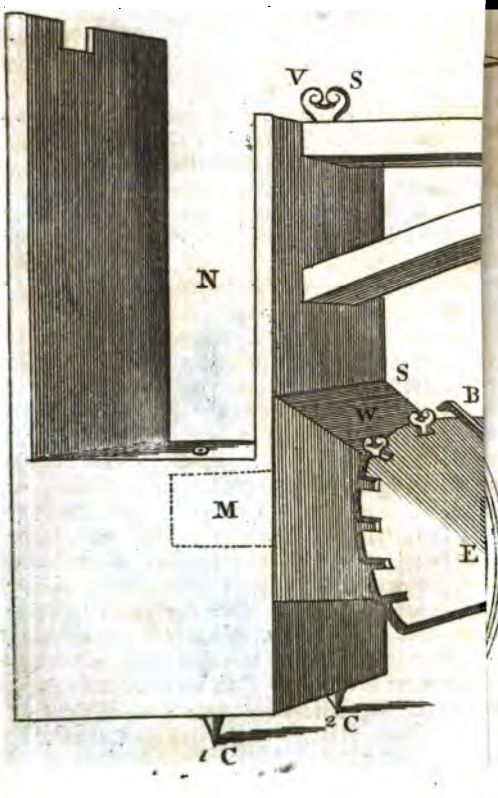
meets it no longer. Whether we make use of an Axis parallel to the Axis of the World, and place it horizontally over the Point, and of an upright Style; or whether we erect a Plate in the Form of an Oblong; or whether we make Choice only of an upright Style to cast a Shadow with its Point; the Support of the Axis, or of the Plate, or of the upright Style, must be yet of the same Height with the Radius used as above, to make the Division of the Hours on an equinoctial Intersection, cutting perpendicularly the meridian Line at the Foot of the Style. An half Equator, drawn flat on the Dial, with five Divisions on each Side the meridian Line, will give you all the Hours possible on the Dial, and point out to you where you are to draw the Lines parallel to the Meridian.

Irregular, or Declining Dials.

The Dials, which we have hitherto treated of, are plain and regular, by reason of the Exactness of their Aspect towards certain Parts of the World. 'Tis the regular Relation of the Plane to certain Circles of the Sphere, which helps us to the Projection of the Shadows; but if the Surfaces where a Dial is required, come once to decline, that is to say, deviate from the Exactitude of these Aspects, by making Angles with the Meridian, acute on one Side, and obtuse on the other, the Rules vary then according to their Positions, which are many. These Rules have been very judiciously explained by *Clavius* and *Dechalles*, and in the new Treatise on Dialling, by M. de *Parcieux* and M. *Rivard*. All Cases are therein properly stated, and all Delineations, which occur in those Cases, are determined by trigonometrical Calculations.

Having hitherto given you but a very slight Sketch of the Method of Geometers, because the History of the Rise of Arts and Sciences, and the first Use the Genius of Man has made of it, confined me within those narrow Limits; I ought not, Sir, to propose to you at present, the making of Dials of all Sorts of Aspects, by the Proportions of Sines, Tangents, and Secants. Yet as most Walls are irregularly situated, built without any View of making them face this or that particular Part of the World, I have attended to supply the Defect of Calculations, by a Machine, which includes almost every Case. By the Description which I shall





Hor

shall give it, you will find a Cone executed by the less skilful Carpenter, under the Direction of two merciless Inspectors, *viz.* the Rule and Compass. It is a very simple Imitation of the Projection of Light and Shadow from one Hour to another, and almost all Sorts of Planes without Distinction. The Use of this Machine is not only mechanical, but mathematical; since Movements measured and conceived are as geometrical, as Lines calculated and proportioned.

Add to the Level N, which we made use of to find the meridian Line, the following Pieces:

Horary Machine. *Fig.* 7.

The Support S mortised into the second upright Beam of the level Machine, is to be joined by the Tenons M, M, one which is secured by the upper Screw U S, the other is traversed with the lower Part of the Level: At the Foot of the Supporter S (which in this Part is cut sloping, and makes with the Horizon an Angle equal to the Elevation of the Equator, here of 41 Degrees) is placed a Semi-circle parallel to the Equator, which is the Name we propose to give it. This Equator is moveable on the Axis A, which runs through it in the Centre, at right Angles, and may be turned when wanted, then stopt again at Pleasure, at the Foot of the Supporter, by the two Screws W. This Equator is divided into 12 or 24 equal Parts, for 12 Hours, or 24 half Hours; if we want any more, the Equator, being moveable, will furnish them, by transposing it. This Equator has been notched of an equal Breadth and Depth at the End of all the Divisions.

The Axis A is fastened in the upper Part of the Support S, and carries its lower Part in the meridian Line, which is necessary in most Dials. On this Axis rolls the Plate L, with its Arm and Tenon B. This Arm turns and presents its Tenon to each of the Notches of the Equator, that as it turns round, it may be catched into it, then come out, to be carried into the next Notch.

The Plate L is a Piece of Wood five Lines thick, and traversed by four Grooves, two Lines and a half deep, two of them parallel to the Axis P P, and the other two crossing the Plate perpendicularly to the Axis T T.

R R are ſeveral Riglets of different Lengths, and of a Breadth exactly proportioned to the Grooves P P and T T, in which they are to ſlide.

Each Riglet has its Line of Proof, and is ſharpened into a Point flattened on the Side, which ſhall ſlide on the Blade; and having its laſt Point on the Line of Proof, theſe Riglets may be in Wood four or five Lines thick, to prevent their warping; thoſe of Iron or Braſs would be much better. They are faſtened on the Plate by means of a Nut and a Screw.

The Arm B repreſents the Sun's Ray, or the enlightened Part of the Plane of any horary Circle. The Plate L contraſting always to the oppoſite of the Arm B, repreſents the ſhadowed Part, or what is left of that horary Plane behind the Axis. When the Sun at B leaves a Point of the Equator, and proceeds 15 Degrees farther, the Shadow, or the Plate ('tis the ſame Thing) will make a Motion of 15 Degrees the contrary Way.

If this Plate, or moveable Shadow, was prolonged as far as on the Plane or Wall which faces it, it would cut its Surface in a right Line; and if we had only two Points of that Interſection, we would have the whole Line (by *Prop.* 7.) Now, our Riglets gliding at Pleaſure through the parallel and tranſverſe Grooves of this Plate, they prolong it; they carry two Points that may be mark'd where they arrive. But if you have two Points of an Interſection, you may join them by a right Line; and thus you have the whole Interſection. As the Arm B imitates the regular Shiftings of the Sun, from 15 to 15 Degrees on the Equator, or on a Circle parallel to it, ſo your Plate, your Shadow, moves with the ſame Regularity: The Riglets prolong each Projection of the Shadow on every Plane, by extending either downwards, or upwards, or ſide ways; the two Points you gain are equivalent to a Line of Interſection, and as they give you two Points of all the Falls of the Shadow, you have conſequently the Interſections of the Planes of all the horary Circles. You muſt take the Riglets ſhorter or longer, according to the Diſtance of the Wall.

The Machine moves regularly, like the Sun, from 15 to 15 Degrees, or from Seven and an Half, to Seven and an

an Half. When the Arm that represents the Sun moves on the East Divisions of the Equator, the Shadow extends itself exactly in a right Line towards the West; otherwise it is quite the contrary. Lastly, as the Action of the Sun is invariable, and independent of the Caprice of the Aspects that are presented to him, the Action of the horary Machine is equally the same, and carries Shadows exactly placed on any Plane. The Difference you will find between the natural Projection of the Shadow, and the artificial March of your moveable Plate, is, that you are ignorant of the precise Quantity of the Progresses of natural Shadows: whereas, knowing here, exactly the March of your Sun B, you know likewise the 15 or the 7 Degrees your Plate has over-run. Join the two Points of the Shadow of each Progress, and you will not only have the Hours and the half Hours, which you search, but an Exact Knowledge of the whole Operation.

This will rectify, by a short Induction, the different Planes to which we are going to apply our Machine.

We need no Apparatus, or Machine, to trace either a superior, or an inferior Equinoctial, both are no more than the Division of a Circle into 24 equal Parts, with an Axis, which pierces at right Angles the Circle, inclined as the Equator.

To trace an horizontal Dial, place the Level and the Axis A well fastened on the meridian Line; the Riglets being brought downward through the Grooves P P, the Points traced by them on the Right and the Left of the South, will imitate all the Shiftings of the moveable Plate, and will depart from the Axis, which will thus become the Center of the Dial. You have no need of searching an equinoctial Line, the Shadow becoming perpendicular on both Sides the meridian Line, will be the Line of Six. To have the 16 Hours of the longer Days, loosen your Equator from under the Screw W, so that you may have eight Notches on each Side of the meridian Line, where the Tenon B may lodge; you have consequently your sixteen Hours.

If the Plane be vertical, either meridional, or declining on either Side; place the Level, the Pins 1 c, 2 c, and the Axis A upon your horizontal meridian Line, bring the Plate

Plate in such a manner as to be an Extension of the meridian Line, by stopping the Arm B in 12, the Riglets sliding still parallel to the Axis; but in ascending they will reach the Wall, and there trace out the meridian Line, and afterwards all the other Intersections that can possibly be on that Plane. If the Plane cuts the Meridian at right Angles, the Riglets will give you four Points, which will form a Line of ten Hours, a Perpendicular to the Meridian: But if the Wall, for Instance, should decline from the true South to the East, the Axis of the horary Machine, when set before it, and prolonged by a Rule, or String, will shew the Point where the iron Axis is to be drove into the Wall, which is the Point where all the Hour-lines meet. However, without searching thus, what follows will give it you. The moveable Plate, left to itself, will fall towards the End of the meridian Line on the Scaffold, and with its two Riglets, upwards or transversally, will point out on the Wall the true meridian Line of the Place, which falls perpendicularly from the Zenith to the Horizon.

The Arm B, carried towards One or Eleven, and successively, on the rest of the Hours, will cause the Plate to move in a contrary Direction, and the Sliders, whether prolonged or shortened, according to the Situation of the Wall, will leave, every where, two Points of each Horary cut. As the moveable Plate has its Center in the Axis, all the Hour-lines will meet in the same Point of the meridian Line, and so direct you where the Axis ought to be drove into the Wall. In order to keep this Axis steady in its Position, parallel to the Axis of the Earth, you must drive a Rod perpendicularly into the Wall, to keep that Axis in its Parallelism with the Axis of the World; we give it a Support called Style, and which may be fixed upright in the Line which represents the Intersection of the vertical Circle, proper to the Dial. This Dial, in Fact, may be considered as an Horizon, different from ours, when the moveable Plate will be found betwixt the Plane of the Dial and the Axis, over against the Point of the Heavens which is vertical for our Dial, the Line which the Riglets, guided by T T, are to give you, then, will be the Substylar, where the Support of the Axis should be placed.

placed. This Line, as you see, is the true Meridian line of the Plane of the Dial, which differs from that of the Place, when the Dial declines. But the Axis being rightly placed, and your Lines truly drawn, the Knowledge of the substylar-line is of very little Use.

It may possibly appear somewhat surprising at first, that the Hour-line of Six, which in the South-dial without Declination, makes a right Angle with the meridian Line, should, in the Declining-dial, make an acute Angle with the same Meridian: the horary Machine helps us to discover the Reason of it. When the Plane fronts the South, the Sliders ascend through P P, in a parallel Position to the Axis, as high as the Axis in the Wall, where they trace a Line perpendicular to the meridian Line, and cross the Center they meet with; but if the Wall draws nearer the Side of the Axis, and farther, from the other Side, towards the East or West, the Riglets which follow the Inclination of the Axis, meet the Side which draws nearest the Axis, before they are extended as far as the Side of the Centre; and as the inside Riglet, by not rising so high, is already shorter than the Axis, the Outside is shorter still. The Line therefore that is drawn obliquely through these two Points to the Center, will make an acute Angle both with the Axis and with the meridian Line. As these Angles vary, like the Declination, they require so many Calculations, as we find new Declinations. The Motions of this horary Machine are as uniform as those of a natural Sphere. Whatever Declination happens, these Riglets fix the Differences from one Situation to another.

No Difficulty attends the Polar dial and Parallel to the Axis. The perpendicular Fall of the moveable Plate gives you the meridian Line, and the Place for the Style. The Distance from the Axis to the Plane of the Dial, fixes the Height of the Style. The Plate that moves round, both Ways, together with the Riglets, more or less prolonged, through the transversal Grooves T T, point out the Hour-lines parallel to the meridian Line, where the Shadow arrives every Hour, from Six in the Morning, to Six in the Evening; and this Dial being formed in Imitation of their Horizon, who live under the Equator, the Sun, after Twelve, will pass under the Horizon, and the Dial will mark no longer.

There is the same Facility in the Execution of a Dial quite Eastern or Western. The Plate in a perpendicular Direction to a Plane of that Aspect, points out the Hour Six, and the Place of the Style. The Distance of the Axis that carries the Plate, and of the Plane, which it rests upon vertically, is the Height of the Style. The same Plate indicates new Lines parallel to the Line of Six, in Proportion as the Sun shifts from a horary Circle to another.

If the inferior equinoctial Dial, which serves as a Model for the superior; if the horizontal and vertical, the inclined, and all the Declinings, which require much Precaution, and so many Calculations; if the Eastern, Western, and Polar, which have Forms so different from the others; if most of the Dials in Use, be formed under the horary Machine, in the same Distribution, and under the same Form, they receive from the Rules of Dialling, founded on the Correspondence of Shadows, to the Situations of the Sun, in the Sphere, it is a Proof, that the Machine represents right the Circles of the Sphere, and the Projection of the Shadows.

Portable Dials are included in the Notion of some one or other of those we have already described. The Ring-dial, however, which is looked upon as preferable to all the rest, is made in a very particular Manner.

Ring Dial.

It is composed of two concentric Circles of Silver, or Brass. The outer is the Meridian of our Horizon; the inner is the Equinoctial. The latter, in order to represent the Equator, is made moveable upon two Pivots, whereby it is fastened to the Meridian, so as to be capable to traverse it at right Angles; and when it is brought to that Situation, it meets with two Supporters, which prop it, and prevent its going further. When it is brought back to its Rest, it falls into two Notches, cut in the Axis, on Purpose for its Reception. If we want to keep that Equator at the Elevation proper for each Horizon, the Meridian must be suspended by a Circle, or Ring, which is brought to the Latitude of the Place on that Meridian; for if the Ring of Suspension runs on the Meridian divided into Degrees, at the Distance of 49 Degrees from the Equator, that Ring is at our Zenith: therefore from the Ring to the Pole, there will remain but 41 Degrees, since the Pole is at 90 Degrees from the Equator;

tor: consequently the Equator of this Machine will be then at 41 Degrees of Elevation on the Horizon; and the Point of the Pole at 49. These four Arches together exhaust the 180 Degrees of the Horizon, and the Distance of the Pole is always like the Distance from the Zenith to the Equator. The Ring, to facilitate all the Displacings wanted for every Horizon, sinks a double fastening in a Groove, which reaches along on the two Faces of the Meridian. The Piece of Suspension runs thus, at Pleasure, as far as under the northern Pole; and, like the northern or southern Latitude, regulating the Position of the neighbouring Pole, it renders the Ring-dial one universal Instrument. The two Poles are represented by two Pivots fastened to the Meridian-circle, or to the two Notches, into which the Equinoctial-circle is lowered. These two Poles, or Pivots, representing the Poles of the World, support a Bridge, which play in them by its Extremities, and crosses diametrically the Equator, brought to its Place to act its Part; for the Equator is of no Use, when folded in its Box, where it becomes concentric to the Meridian.

The Axis is represented by a long and narrow Aperture, which riggles along the Middle of the Bridge. The Use made of this Aperture is, to lodge in it a small Piece of Metal, which moves, with a Hole through, called Cursor, and which running backwards and forwards under the Sun, according to the various Declinations where it arrives, from one Day to another, is found exactly between the Planet, and a Point opposite on the inner Edge of the Equinoctial; whence it follows, that the Sun, the Cursor, and the Point opposite in the Equator of the Ring-dial, being on the same Line, that Point of the Equator must necessarily be enlightened through the Shadow which becomes it.

To direct the Person who makes Use of the Ring-dial, let a Circle be drawn upon Paper, equal in Diameter to the Aperture, which one judges proper to give to the Bridge; the Length of that Aperture is equal to our Arch of the Meridian of 47 Degrees, to take in all the Declinations of the Sun; and the Circle drawn, which has that Aperture for a Diamater, represents the Ecliptic with its twelve Houses. That Circle, therefore, is divided into twelve equal Parts, the Points thereof are joined two and two by parallel Lines, which make Spaces, narrower towards the

Tropics, and wider towards the Equinoxes, as in *Fig.* 1. each of the six divisions, which serve for twelve Months, are divided afterwards into three Times 10 Days, or into six Times five, to suit, as near as possible, the Position of the Cursor, to the actual Declination. All these Measures are carefully transferred on the two Edges of the Bridge. When this Instrument is intended for Use, the Cursor is put to the Day of the Month, and the Suspension to the Latitude of the Place: we turn, afterwards, the flat Side of the Bridge, towards the Sun, and his Rays fall exactly on the Edge of the Equator, except in the Days of the Equinoxes, when the Sun turning round the brass Equator, as he does round the celestial, can only cast the Shadow of the upper Edge, on that opposite to it. The Hour of 12 at Noon must also be excepted; because the Sun, shining then on the brass Meridian, throws the Shadow thereof upon the opposite Edge, where the Hour of 12 is marked. One may know, however, that it is Mid-day, by the Dial having no radiant Point at all.

Those who examine this Instrument with Attention, will say, perhaps, that the Sun being in the Equinoctial (in R *Fig.* 8.) is inclinable to shoot its Ray through the Center N, upon the opposite Edge P. But if the Sun declines from the Equator, the next Day, their Radiation ought also to remove from it. Let us transfer the Sun to S, in its greatest northern Declination, it will cast its Ray to the Center N, and consequently, to 23 Degrees and an half beyond the Equator; but by no Means to its Edge P; we shall not therefore have on it the bright Spot required. You placed the Cursor on the Bridge in I, for the 21st of *June*, What will follow? If you join with a Thread, the Declination S, the Point of the Cursor I, and the Fall of the luminous Point P, with the Edge of the Equator; your Thread will be bent at the Cursor, and you will have a Curve line. How then shall your Point come to the Place where you expect it? And yet it will come there.

This seeming Oddness discovers the Capacity of the Inventor; his Way of Reasoning was this. Let several Brass Meridians (armed from one Side to the other with a Plate pierced in the Center, and cross at Right angles an Equator placed on the Meridian) be exposed to the Sun, at divers distant Parts of the Town; such are the Circle P A R E,

RE, and the other great Circle it contains. When the Sun is at the north Declination of 23 ½ Degrees, its Ray, in all these Instruments, will pass from S to N, and will go on the other Side at 23 ½ Degrees from the Equator. If we expose the moveable Plate to the Sun, in Proportion as it describes another Parallel, more or less declining from the Equator, the End of its Ray will describe a like Parallel at the other Side of the Equator. The Reason, why in these Instruments so distant from each other, the Effects are the same, is, because the Circles of all these Instruments being respectively parallel among themselves, and parallel to the Circles in the Heavens, the Sun's Rays fall exactly at the same Day, on the same Degrees, and all these Rays are so parallel to each other, that they may be considered as one and the same Ray, or rather, a Mass of Light composed of parallel Threads. If therefore, under the Diameter H E, of my Meridian P H R E, as under a Tangent, I imagine, or describe a new Sphere, another Meridian of the same Radius as the preceding one, the Sun will as naturally dart its Ray, the 21st of *June*, on the 23 ½ Degrees of Declination through the Center of this second Sphere, as he does on the several other Spheres above-mentioned. This being settled, let the Arch of 47 Degrees of S M, be laid on the Plane of the former, we may judge of all the Declinations by the two farthermost towards the North S, and the southern Part M. On the 22d of *December*, as the Sun glides through in N, he will glide, likewise, through M P; because P is the Center of S M, as N is the Center of s m: and on the 21st of *June*, as his Ray lay along s N, he will lay another parallel Thread of Light along S P. Let us change the Diameter, or the Tangent H E, into a long moveable Plate, which is slit to receive a Cursor, which may slide along a Distribution of the Days of the Year, marked on the Edge of the Slit. I have already two Points in the Line of the Sun's Ray in this Sphere for the 21st of *June*, that is, the Point of the Declination S, and the Center P. Let us bring the Cursor upon the same Tangent-line in I, it will be found between the Center P, and a fourth Point, which is the Sun. The Cursor, therefore, put that Day at I, will suffice to enlighten the central Point of the Sphere S M, applied to the Sphere P H R E. Therefore, I shall have the

same Effect the 22d of *December*; for the Cursor being put at D, will discover to the Sun, the central Point P.

If, instead of a Portion of an imaginary Sphere, or described only in the Plane of P H R E, I should fasten to the moveable Plate H E, a brass Sector S M P, and move the Plate so as to be always opposite to the Sun's rolling from 15 to 15 Degrees on some Circle, parallel to the Equator, the Sector so fastened to the Plate would move with it; and as P is both the Vertex of the Trigon, and the Center of the Sphere S M, and together of the same Radius as the Sphere P H R E, and the Equator contained in it; the Plate moving, the Sector, and the Center P will move likewise as the Sun moves, from 15 to 15 Degrees, from a horary Circle to a horary Circle, without forsaking the Edge of the Equator: consequently the Sun, in any Declination, will have a Propensity towards directing its Ray to P; and will direct it, in Fact, if the Cursor is rightly placed to give it Passage. So that independently of the Sun's Position in the Meridian P H R E, it will keep its Parallelism in the Sphere S M: It will always touch, and infallibly meet the Centre on the Equinoctial, where the Sector carries its Vertex; and though we should, afterwards, take away the brass Sector; nay, though it had never been drawn, the Cursor well placed on the Marks of the Bridge gives you, with the Sun's two Points, tending in a right Line towards another Point, corresponding to them in the little Equator; every Day, therefore, and every Hour, when the Sun is on the Horizon, he will cast a luminous Spot on the Degrees of the Equator, relative to that of the horary Circle, where the Sun is found. Thus the Effect of the Ring-dial is demonstrated.

The *Astrolabe* should naturally follow the Instruments afore-mentioned, and still better, on Account of the great Number of its Uses, which serves to shew with what Success Man knows how to apply Geometry to the Determination of the Hours, Days, Declinations, Altitudes, and Measures of all Sort of Distances, taken either on the Earth, or in the Heavens; but what I have prepared on that Subject is so prolix, as to make me tremble for you; therefore I have suppressed it. If at any Time the Beauty of the Matter invite you to study it with some Application, you may have Recourse to what M. *Dion* has wrote on that Subject.

Subject. It is now above two hundred Years ago that *Stoflerin* taught us, with the greatest Accuracy, the Manner of making an Astrolabe, and of using it. His Stile is prolix, and smells of the Simplicity of a Workman, but of an excellent one.

OF MECHANICS.

DIALOGUE XIV.

LET us continue to run over the other Practices of the human Sciences, which instead of amusing us with out-of-the-way, transient Speculations, render, on the contrary, those Sciences useful to us, and enrich our Mind with permanent Realities. Nothing of that Kind is more valuable than the Machines and the Direction of the moving Powers, which bring under Man's Laws all the Productions of the Earth, and make of him a true Image of the Creator.

Tho' we raise him to so honourable a Parallel, drawn from the Scripture and Experience, we do not lose Sight of his natural Weakness: he has but a small Share of Strength: he can carry a light Burden, drag along a Body of a moderate Weight, or push a little Mass to a short Distance: but all those Effects are confined within very narrow Limits, and, in Reality, very inferior to the Extent of his Necessities; but it is even his own Weakness, that renders his Industry more conspicuous. The supreme Wisdom, by creating him so little and so weak, had, in all Appearance, no other Intention, than to render him active and industrious. Sensible of his Indigence, he turns himself every Way; he calls to his Succour Force against Force, Velocity against Gravity, and Gravity against Velocity, one Shock, in short, against another. By the Assistance of Mechanics, this little Being, not above five or six Feet high, with two Arms only, will dispatch as much

Work, as a Giant, whom one would imagine to have a Thousand. The large and massy Bodies, with which Nature abounds, would seem every Moment almost to drive him to Despair. What will become of him when any violent Tempest arises? How will he cross rapid and deep Waters that obstruct his Passage? By the Power of Mechanics, he keeps Nature in Subjection, the Winds are subservient to his Direction, and convey him at Pleasure beyond the Seas; he erects such Edifices, as will serve from one Age to another; he throws such a * Bridge over the *Rhone*, that his Posterity looks on it with Admiration, and ascribes it to no less a Power than that of the Holy Ghost. Take Mechanics away from Man, and you render his Thoughts barren. All that is most beautiful upon Earth, is owing to the Mechanics. The most common Machines, made use of to supply his Want of Strength, are the Levers, the Beam, or Balance, with equal or unequal Arms; Pulleys, simple or compounded; the fixed or moveable Pulleys; the Axle-tree, and all Capstanes; the Crane, and Calendar: the dented Wheel, the Screw, the Wedge, and Mills of all Kinds. These first Machines, and many others, brought to a Manner of Acting common to them all, are reduced to the Lever only, the Idea whereof is very simple.

The Lever.

The first that undertook to remove a Pile of felled Trees, a Stone of any large Bulk, finding no Proportion between the Strength of his Arm, and the Resistance of the Mass before him, thought of sliding underneath a strong Bar, and of placing under that Lever a Prop, at some Distance from the Insertion. Thus he made of it a Swipe, divided into two Parts; one shorter, taking it from the Mass to be lifted up to the Prop, the other longer; that Length taken from above the Block to the outer Extremity of the Lever. He suspected that the Weight of his Body, at the upper End of this Bar, would bring it down, and by that Means, the other End would lift up the Tree a little. And accordingly he succeeded in this first Attempt, which gave him an Insight and Encouragement for future Trials; after this, he let the Tree fall, put the Block nearer, and having thereby lengthened the Fore End of his Lever, without growing

* Called the Pont *St. Esprit*.

Vol. V. pl. IV. pa. 225.

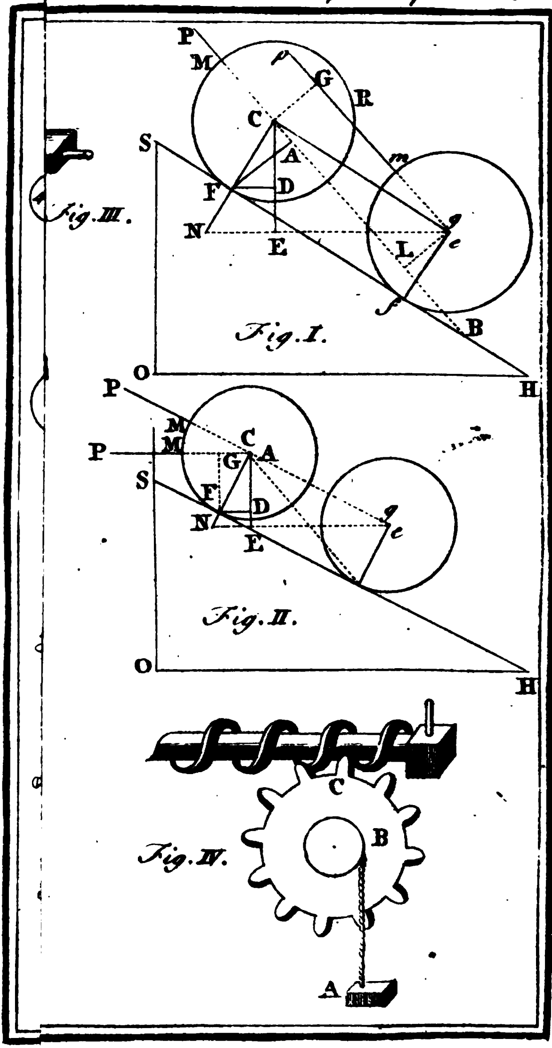


Fig. I.

Fig. II.

Fig. III.

Fig. IV.

stronger himself, he gained a still greater Advantage than before. He exerted a Power that was not in him. He discovered afterwards, by several Trials, that the longer the Lever was between the Prop and the Agent, the less Strength was required in the Agent to pull it down. Thus, by Degrees, he became capable of moving very ponderous and solid Bodies, and of turning, at least, topsy-turvy, what he could not carry away. He made it, therefore, roll before him, from one Place to another; at last, he became so expert in that Art, that he cut Columns in the remotest Parts of *Africa*, and raised them afterwards at *Memphis*, or *Rome*.

Not contented with conquering, he learnt how to improve his Advantages, and make use of his Victory. Let us consider his Success by Means of a Figure; now comparing the inequal Lengths of the Lever in the various Shiftings of the Block a; then changing Levers, without displacing the Prop, and supplying sometimes the Place of his Hand by a Weight, suspended at the End of the Lever b: he found by Experience, that in all these Cases, the Disadvantage which he met with, from the Increase of the resisting Power d, was sufficiently compensated by the Increase of the Length of the anterior Arm b, over the shorter c. He perceived likewise, that when the long Arm b, which he grasped, was in the same Proportion with regard to the shorter c, as the Resistance d was with regard to the Agent b, there was always an Equilibrium. Happy Remark! the true Source of Light and Profit, which strengthened his Hand, by a single lengthening of a Pole, and facilitated the Discovery of still more useful Machines. To procure the desired Effect, in an infallible and regular Manner, he divided a Rod very straight and smooth, or an Iron Beam, conceiving that the Lever would always produce the same Motions, whether it was supported by a Fulcrum, or Prop at Rest, or suspended with a Cord, or Hook; he placed the fixed Point, or the Point of Suspension, between the End of the first Division and the Beginning of the Second; so that the shorter Arm of the Lever had but one of the ten Parts, and the longer, nine. To place them in Equilibrio, according to the Proportion observed, he hung, at the End of the shortest Arm, a considerable Weight,

Plate IV. Fig. 1.

ſuppoſe 18 Pounds, and inſtead of ſix Pounds, which is one Third of the Height above, on the ſeveral Diviſions of the other Arm, and in moving the Weight backwards and forwards, he perceived that the ſix Pounds Weight was in Equilibrio with the 18 Pounds, when it was ſtopped at the third Point. Then, inſtead of his Hand, the full Strength of which he could not as yet exactly eſtimate, he made a ſix Pounds Weight, which is a Third of the preceding, run over the different Points of the other Arm; and perceived thereby, that the ſix Pounds Weight was in Equilibrio with the 18, when ſtopped on the third Point, conſidering as nothing that Part of the Arm beyond the Point 3, he concluded that there would always be an Equilibrium between the ſix Pounds Weight, and that of 18, if the long Arm was from the Weight to the Prop, only three times the Length of the ſhorter that carries the 18 Pounds Weight. From hence he clearly perceived, that the Weights were in an inverſe Ratio of the Diſtances, or that when the Diſtance from the little Weight to the Point of Suſpenſion exceeded the Diſtance from the greater Weight to the Fulcrum, as much as the greater Weight exceeded the leſſer, there was an Equilibrium: for as 18 Pounds are the Triple of Six, likewiſe three Feet Diſtance is the Triple of one; and the leſſer Power recovers its Diſadvantage, with reſpect to the greater, in the ſame Proportion as its Diſtance from the Prop or Fulcrum exceeds the Diſtance of the greater. To ſtrengthen that Knowledge, our Obſerver removed the ſix Pounds Weight, ſlipped on one of three, on the ſame Arm, and found it in Equilibrio with that of 18, when it arrived towards the Diviſion b; a new Proof of the inverſe Proportion: for, as the Arm of one Foot, which carried 18 Pounds, was but the ſixth Part of that of ſix Feet; reciprocally, three Pounds, carried by the latter, were but a ſixth Part of the 18 Pounds which were ſuſpended at the ſhorter Arm.

At laſt, upon trying to put different ſmall Weights at the End of the Rod, at the Point more diſtant from the Point of Suſpenſion than was the 18 Pounds Weight, he found he could not have the Equilibrium, but by placing upon it a two Pounds Weight; becauſe, as the Arm that carries the great Weight is but the ninth Part of nine Feet, likewiſe the two Pounds Weight is but the ninth Part of 18 Pounds.

The

The Observer easily perceived, that the nine Parts of the Iron Beam, compared with the single Part of the shorter Arm, had an intrinsick Weight, a Quantity of Matter, which ought to be taken into the Account, and was a small Obstacle to the Correctness of its Proportion, not in the Principle, but in the Application. The Lever, in its Principle, is a Line of no Thickness; in the Execution, 'tis really a solid Mass. He conceived also, that the Divisions might not be perfectly equal; that the Matter of the Lever might be unequal in Weight from one Division to another; that there might happen some Obstacle, or even Disorder in the Effect it should produce; sometimes by the Frictions of the Lever on the Prop or Suspension: sometimes by the Impressions of the Air, which might dry up a long Rod, without affecting the more knotty Part; or, sometimes, by other Causes, against which he taught he should caution himself. He learnt, by Degrees, either to prevent or correct them, in such a Manner, as to possess entirely, or almost entirely, the advantageous Proportion, which, with a slight Strength, submitted to him a great Resistance.

It was a great Satisfaction for our first *Archimedes*, that he could say to himself, As I am Master of dividing a Lever into two unequal Parts, the longest of which shall be to the shortest as one Hundred is to One; it is as much in my Power to hang one Pound Weight at the longer Arm of my Lever, and a hundred Pounds Weight at the shorter. Thereby I place them on a Level, I bring them to an equal Product; a hundred Pounds multiplied by one Foot, being the same Total, as a hunded Feet multiplied by one Pound. By Means of this Medium, I am sure, that one hundred Pounds will not over-ponderate one, and that with two Pounds, I will move two hundred Weight; with ten Pounds I will counter-balance a thousand; and if to the Counterpoise of ten Pounds, hanged on the longer Arm, I add only one Ounce, or the Impulsion of the Hand of a Child, that little Hand, that could scarce lift a Pound Weight, will lift up a Thousand, with as much Ease, as he would his Coral to his Mouth. But we will leave here the Marvellous, said he, and think at present of Profit. If the Length of the Lever cumbers me, I can shorten it, and apply to it a greater Force. Instead of a Weight, I

will put my Hand to it. Instead of my Hand, that may be of Service elsewhere, I will apply the Strength of an Ox, or a Horse; and I will then not only move a hundred Weight, but a thousand, or a Million. Who knows but in Process of Time, the Force of a running Stream may be applied to this Lever, or even the Action of the Wind, or any other Power in Nature: and it is not so much a great Strength, that is at present to be sought after, as the wise Application of a moderate Power.

If this Principle, once discovered, be as true as 'tis commodious, I must find it every where the same, notwithstanding the infinite Diversity of Things to which it may be applied. Let us see if it answers as well in very different Cases.

Fig. 3. Let us hang up a Lever, whose longer Arm be only double the shorter, in the Ratio, as it were, of 2 to 1, of two Feet against one Foot. The Ratio of Strength to Strength being inverse of the Distance to the Distance, my Hand applied to the End of the longer Lever must make, in an inverse Ratio, against the resisting Weight, an Effort of one to two, since the Distance to the Distance is here as 2 to 1. My Hand, therefore, will make an Effort of two Pounds against a Weight of four, and of 20 Pounds against a Weight of 40. Applied, on the contrary, to the shorter Arm of the Lever, it will act to a Disadvantage, and will use the Force of 40 Pounds against 20 Pounds Weight.

Fig. 4. Let us now change our Proportion; and give ten Feet to the longer Arm, and two to the shorter; two is the fifth Part of 10; so to put the Weights in an inverse Proportion, we will hang, for Instance, three Pounds to the longer Arm and 15 to the shorter; three being the fifth Part of 15, as two Feet are the fifth Part of 10. Thus you have the Equilibrium: It will be the same of ten Pounds in the greatest Distance, and thirty in the lesser. But let us grant here something to our own Conjectures; and suppose, that the 15 Pounds Weight must over-balance the three Pounds, notwithstanding the Excess of the Distance of three Pounds from the Fulcrum or Prop. Let us even make a Supposition thereof, for we will give it up if Occasion require; and perhaps, by proving the Rule a-new, we will find the Reason of that Rule. The

The two Arms of the Lever playing upon the Fulcrum describe Part of a Circle; the shortest the little Arch a the longer the Arch five times bigger b. For if the 15 Pounds Weight descends one Foot, the three Pounds Weight, being five times more distant from the Support, will move five times the Space, and rise five Feet. Now 'tis evident, that the three Pounds Weight acts with the Power of three Pounds, at every Point of the Arch it runs through: The Action is the same every where; so that the 15 Pounds Weight meets with the same Resistance, as if a three Pounds Weight was at every Point of the great Arch. The 15 Pounds Weight likewise acts with the Power of 15 Pounds, at every Point of the Arch it describes; but the Arch traced by the lesser Weight, is five times larger than that which the greater Weight runs thro' in the same Time, and if the 15 Pounds Weight move through one or two Points, the three Pounds Weight will move faster five to one, and ten to two; they are therefore in Equilibrio; for the Action of 15 Pounds repeated a hundred times, or applied to 100 Points, is the same Thing, as the Action of three Pounds repeated 500 times, or applied to 500 Points. Thus, whilst the 15 Pounds are moving through two Points only, and act with a Power equal to twice 15 Pounds, or the Sum of thirty, the three Pounds will run through ten Points, and act with a Force proportionable to ten times three Pounds, which is equal to thirty. The Resistance, therefore, that the great Weight meets with in describing each Point of its Arch, is the same, as if it lifted at once five solid Bodies of three Pounds each, *i. e.* a Weight of 15 Pounds. But as the great Weight, in traversing one Point, cannot force the lesser to traverse more than five; the lesser, which describes five, cannot force the greater to traverse more than one. They keep each other in that Process, the one cannot overbalance the other; and thus the Supposition made, that the greater would over-power the lesser, is found to be false. They are two different Powers, which are become equal; and, by a slight Impulsion, we may, at Pleasure, cause one or other to give way. 'Tis no difficult Matter for a Man to put 3000 Pounds on one Side, and 15000 on the other; and when he has so done, he may elevate or depress the 15000 Pounds by the Tip of his Finger only; and

and if from the Sum of the Forces it requires or over balances, we substract what it has left, we shall find that he gains 4 for 1, 12000 for 3000; he may increase his Gain, however, without augmenting the Expence, or Power 3, for it suffices to move it farther from the Fulcrum. If it be moved so far that the shortest Arm be to the longest, as 2 to 20, which is one tenth of twenty, the smaller Weight will be the tenth Part of the greater; three Pounds will be equivalent to 30, and 3000 to 30000.

Direction of Powers.

Together with the grand Principle of Mechanics, we begin likewise to see the Ratio thereof. If that Ratio to which we attribute the regular Effects of Mechanics be true, in Proportion as that Cause shall grow weaker, we shall find that the Effects will grow weaker likewise. This will happen when the Directions of the moving Powers will be no longer the same, either between themselves, or with regard to the Fulcrum. In the Application of moving Powers, it is indifferent whether the Power ascends or descends; whether the Weight gravitates either in following its natural Propensity, or moving in a contrary Direction; it is only required, that the Action be always the same, and the Powers compared together should act with Uniformity. Now this Uniformity of Forces, which maintains the Equilibrium, must cease when the Directions of the Forces shall happen to cease; for the Lever, to which they are immediately apply'd, or on which they are suspended, is either straight, as g b (*Fig.* 5.) or bent as f b. If it be straight, the Directions must be parallel, as g i b h, and if it be bent, the Directions must be perpendicular to their Part of the Lever, as f g is to f l, and b h to l b; where the Directions are parallel, as b h and g i; then the Arms of g b are the Measures of the Distances to the Fulcrum, and of the Proportion of the Powers; but if these Directions be oblique, or inclined on each other, as c g, or d g with regard to b h; then these Directions destroy the Proportion between the Distances and the Powers. The Action which goes from g into d, draws in Part towards i, and in Part towards b. It is therefore divided; it is no longer what it was, when entirely re-united in the Direction g i. Likewise the Power g c, the Lever g, draws partly towards i, and partly towards a. The nearer it will approach,

proach, and the more it inclines to a, the more Strength it will lose towards i; therefore the Perpendiculars b h and g i must be drawn to have a Computation of the Forces by the Distances; therefore the Directions must be perpendicular on the straight Lever, if we want to make use of its Arms, to measure the Powers.

If the Lever b is bent in l, as f b, then the Power applied to f, will act either according to the Direction f e, or to that of c f; or will draw towards K. Little or no Advantage is gained by the Direction f e, which is oblique, with regard to the Lever f, as g d, with regard to the Lever g b. As you destroy the Equilibrium of two Powers, when you turn the Direction of one of them towards e; you destroy it also, by drawing or acting towards K. To recover the Proportion of the Equilibrium, you must carry the Perpendicular c f on the bent Lever f; and then the lesser Power c is to the greater h, as the lesser Arm 2 b, where the greater Power acts, is to the Arm 3 f, on which the lesser Power acts.

From these Observations proceed two or three Rules of great Use. 1. If two Weights or Powers be in a reciprocal Ratio of the Distances extending from the Fulcrum to the Perpendiculars, there is Equilibrium.

2. If two Weights or Powers, one whereof following its Direction, and the other moving contrary to his, pass thro' Spaces that are reciprocal to each other, as the Powers are; and so as that the large Spaces may be run through by the lesser Power, and the lesser Space by the greater Power; there likewise will be an Equilibrium; because the Action of one Power is equal to the Resistance which is made by the other.

3. If the Distances to the Fulcrum be equal, and the Spaces which are run through be also equal, there can be no Equilibrium, unless the Powers be equal. And as the Equilibrium can be found, by making the Powers equal; likewise the Equality of the Powers are easily found by searching the Equilibrium.

The Instrument used for this last Process is the common Balance or Scales; because the Arms are made of equal Lengths. Fig. 6

The Instrument with unequal Arms, used in the preceding Experiments, are the *Roman* Balance, or Statera. Fig. 10.

Expe-

Experience and Reaſoning have brought theſe Inſtruments to Perfection, by the Suppreſſion of ſeveral Defects, contrary to the Rules above-mentioned.

Modern Balance.

The ſeveral Parts of the Balance, are the Beam, the Axis, the Tongue, and the Scale.

Fig. 6. and Fig. 7.

Firſt, The Arms of the Beam muſt be equal in Length and Weight, becauſe the Merchandize, which is put into one of the Scales, ought to be as ponderous as the Weights in the other; which would not be, were the Arms unequal.

Fig. 7.

For tho' one of the Arms ſhould be of five Parts, ſuppoſe five Inches, and the other but four, they would appear in Equilibrio, ſhould the ſhorter Arm be a little thicker than the other. The Goods placed on the longer Side, traverſing a greater Space than the Weight on the ſhorter, would oppoſe to it a Power ſufficient to make an Equilibrium, though it ſhould weigh but four fifths of the Weights in the other Scale; and out of five Pounds, there would be one deficient, and one Ounce out of five Ounces. For as the Diſtance of the Weight from the Point of Suſpenſion would be but the four fifths of the other Arm, reciprocally the Commodity ſuſpended at this would be but four fifths of the Weight.

Fig. 8.

Secondly, The Arms of the Beam ought not only to be of equal Lengths, but the Beam ought likewiſe to be very ſtraight, otherwiſe the Scales will be deceitful. To diſcover this Defect, let us conceive the Weight and Commodity to be in Equilibrio, when the Beam is level to the Horizon: For we ſuppoſe the Arms equal, and the Points of Suſpenſion of the Scale equally diſtant from the Axis: But if the Scale be bent, if the Arms of the Beam incline downwards, and the Weights are to aſcend, as is cuſtomary in Commerce, the Weight which from the Direction a, where it ſtood, aſcends into b, is found in a Direction more diſtant from the Center; and, on the contrary, the Commodity in deſcending, will paſs in a Direction nearer to that Point. Thus, inſtead of a ſingle Draught, which is allowed the Buyer, to ſatisfy him that he has, not only his Weight, but an Overplus; it will be abſolutely neceſſary to add ſomewhat conſiderable to the Commodity, to put it in Equilibrio with the Weight, ſo as to make it aſcend:

Since

Since the Change of Direction renders the Weight on the one Hand stronger, and gives less Power to the Commodity on the other. So that to make the Draughts, there must be more added, when the Beam is bent downwards, than when it is straight, and horizontal. Such a Balance, therefore, is disadvantageous to the Seller. If the Beam was bent outwards, it would be a quite opposite Defect; since the Commodity in descending, to make the Weight ascend, would require a more advantageous Direction and more distant from the Center; whereas the Weight would lose, by bringing its Direction nearer the Axis, which would injure the Buyer.

The Balance would not be free from the same Defect, if the Beam being straight, the Points of Suspension were below the horizontal Line, which should pass through the Axis. The Middle of the Beam would describe a small Circle round the Axis, so that a Radius of that small Circle would gain in ascending a Direction more distant from the Axis; and the other Radius, in descending, would be in a less distant Direction, therefore the same would happen to the Basons or Scales. To avoid this Inconvenience, it is necessary, that the horizontal Line which traverses the Beam, should cut the Axis, and the Holes where the Scales are suspended. Thus the whole move always on either Side in parallel Directions. If the Weight and the Commodity, being in Equilibrio, should quit all these different Directions, to search only that where they are on a Level, it is the Effect of the Direction of Nature, which always brings Things of an equal Weight to an equal Distance from the Center of the Earth, provided they play freely in the Fluids that surround them.

Fig. 9.

To know exactly when the Beam is horizontal and level, a Tongue is fixed upon it perpendicular to the Length of the Beam, so that when the Arms are exactly parallel to the Horizon, the Tongue is hidden in Trutina: whence it cannot come out on either Side, but it discovers the lowering one of the Scales, and the Superiority of the Weight that gravitates in it. But that this Mark may be sure, he that weighs the Commodity ought to hold the Trutina by its Extremity; or have it freely suspended by a Ring, rather than to grasp the

Fig. VI.

Trutina,

Trutina, at the Risk of keeping it inclined; in which Case, the Cock would slip from under the Trutina, without discovering exactly whether the Beam be truly horizontal, or not.

Roman Statera. How commodious soever the Balance was, for the Simplicity of its Service, it was soon perceived, that it was embarrassing in Commerce, with regard to the Quantity of Merchandize to be delivered: In Proportion as the Quantity changed, the Weights were to be changed; and when the Parcels were large, one of the Scales was to be loaded with a prodigious Weight, and these Weights were to be changed often, not without much Trouble and Difficulty. Another Instrument, therefore, was presently found out for weighing, where one single Weight, always at hand, and easy to be moved, could be in Equilibrio with different Quantities of Merchandize. We will now shew you the artful Distribution of one of the Arms of this Instrument.

Fig. 10. *First*, Though the Lever was divided into two unequal Arms, yet in that Inequality of Length, it was practicable to make them stand in Equilibrio, by making the long Arm thin, and the short one thick; or even to allow that the longer Arm should overbalance the shorter; the Thing was indifferent; provided that in making the Division of the longer, Regard should be had to the Overplus, which could have broke the Equilibrium; and provided likewise, one should make a just Computation for it.

In the first Case, where the Thickness of the shorter Arm brought in Equilibrio with the longer sufficiently weakened, nothing more easy than the Divisions of this latter. The Length of the shorter Arm was taken from its Extremity where the Hook b is suspended to the Point of Suspension or Center of Motion a, and that Length was transferred on the other Arm, as many Times as it may be contained in it. After that, by suspending a small Weight, as, c, of one Pound, and rendering it moveable by Means of a Cursor or Ring d, it was easily made to pass along the Arm, through all the Divisions, 2, 3, 4, or more, if there were more. This sliding Weight, placed at the Division 1, was found exactly in Equilibrio with one Pound of any sort of Goods, suspended at the Hook b; the

the two Arms, at the same Time, equiponderating each other. The Pound on each Side was the same Weight, and at the same Distance from the Center, and consequently equal. But when the Weight c was moved to the Division 2, it was then once more distant from the Center than the Pound placed in b, where it made a double Effort agreeable to the Distance; therefore three Pounds of Merchandize were wanted to equiponderate the Pound c brought into 3; four Pounds of Goods to counter-balance the same Pound c carried on the Division 4, and 20 Pounds in Equilibrio with a single Pound, which equiponderate twenty, when placed at the twentieth Division. This is no more than a new Application of the reciprocal Computation of the Smallness of one of the Powers, by the Length of the Lever, and the Shortness of the other Lever by the Greatness of the Power. In all these different Positions, the Arms of the Lever preserve their intrinsick Equilibrium, and in no wise affected the Truth of the Proportion. But in the other Case, that the two Arms of the Lever were not to be brought to an Equilibrium, another Method was wanted to find the Direction of the longer Arm, which is as follow.

Secondly, The longer Arm exceeding, for Example, the shorter by half a Pound, so that half Pound, suspended at the Hook b b, by restoring the Equilibrium, was a Proof thereof: then, to have a just Division of the longer Arm, it was judged necessary to divide the lesser into two equal Parts, and carry one of those Halves of the smaller Arm on the greater, from the Point of Suspension a a, to the Point 1; taking afterwards the total Measure of the shorter Arm, and repeating it on the longer, so many times as it could contain it. This done, if the Mass e weighed one Pound, it was found, according to Expectation, that being at the Point 1, which is half the Length of the shortest Arm, it equiponderated with one Pound of any Commodity hung at the Hook b b; for, *first*, one half of this Pound is the Compensation of the Excess of the longer Arm, to put it in Equilibrio with the shorter.

Fig. 11.

Secondly, The other half Pound is to the Pound put at 1, as the Distance 1, half the shorter Arm, is to the Totality of that Arm. By Means of this Precaution, which repairs the

the Inequality of the Weight of the Arms, the small Weight of one Pound brought to the Division 2, must be equivalent to the Merchandize of two Pounds Weight at the Hook; at 3 to 3 Pounds, and at 30 to 30 Pounds.

This Division, which surprizes at first View, is founded on the same Rule as the former that is so simple. Let us suppose, for once, that the two Arms of the Statera are in Equilibrio; it is evident, that the Weight of one Pound put on the Point 1, which is half the Length of the shorter Arm, will equiponderate half a Pound suspended at the Hook b b, since the Distances of the Weights from the Points of Suspension are reciprocally as those Weights; and that we have here a double Weight with a half Distance, against a half Weight with a double Distance, without any Trouble, in regard to the Arms, which are equal in Weight. But if the Arms be unequal, so that the longest weighs double the shortest, there must be half a Pound more hung upon the Hook, in order to bring the Arms to an Equality. The Weight therefore of one Pound being put at 1, and the Stilliard being in Equilibrio, there must be, of course, one Pound of Goods at the Hook. For the Equilibrium proceeds from that the longer Arm, weighing double the shorter, the Pound on the shorter is once more distant from the Center, than the Pound on the longer.

If the sliding Pound be brought to the Division 2, which is double the Division 1, then the Distance of the Hook from the Point of Suspension being two Thirds of the Distance from the sliding Weight c c to the same Point; reciprocally three half Pounds at the Hook should, in all Appearance, equiponderate with two half Pounds e c at 2. But we should remember, that the exceeding Intrinsick of the longer Arm on the shorter, is of half a Pound; there is wanted, therefore, one half Pound more at the Hook, to keep up the longer Arm. Thus the Stilliard being in Equilibrio, when the sliding Weight is at the Division 2, there will be two Pounds of Goods at the Hook.

By this Manner of Reasoning it appeared plain, that, when the moveable Weight came to the Division 3, 4, 5, 30, and 40, there would be necessarily in the Equilibrio, 3, 4, 5, 30, and 40 Pounds of Goods on the Hook.

If, therefore, there was but a Quarter of a Pound required at the Hook, to keep the Beam level, after having divided

divided the short Arm into four equal Parts, it was sufficient to lay off three of those Parts on the Beam from the Point of Suspension, and there mark 1, and then proceed to the Division of the Beam, by repeating the whole Length of the short Arm, as many times as it may be repeated from 1 to the End of the Beam. The sliding Pound c c, being put at the Point, which expresses three Fourths of the Length of the short Arm, should, in all Appearance, have equiponderated with three Quarters of a Pound on the Hook: but because there was a Quarter of a Pound more wanted to keep the long Rod in Equilibrio with the short Arm, it followed, that the Pound Weight at the Point 1 required for the Equilibrium one Pound of Goods at the Hook, two Pounds when it arrives at 2; and 20 Pounds when it comes at 20.

When, to keep up the Beam, two Ounces only were wanted at the Hook, then the lesser Arm, or the Distance from the Hook to the Point of Suspension, was divided into 16 equal Parts. From that Number as many Points were deducted, as there were Ounces wanted at the Hook to keep the longer Arm in Equilibrio, and the remaining Parts were carried on the Rod from the Point of Suspension. If three Ounces were wanted to keep both Arms in Equilibrio, then 13 Parts of the shorter Arm, which is the Excess of the Number 16, were carried on the Number 3; and the sliding Mass being of 16 Ounces, could not fail of making an Equilibrium at the Point 1, provided that with 13 Ounces hung at the Hook, there be three more put to counter-balance the Weight of the longer Arm. There should have been then one Pound of Goods at the Hook, when the sliding Weight was at 1. The rest of the Divisions being afterwards set off by the whole Length of the short Arm, there were two Pounds at the Hook, when the sliding Weight was at 2, three Pounds when it came at 3, four Pounds at 4, and so on as before.

Thirdly, There was a third Case, which required a different Kind of Division; and that was, when the short Arm should chance to be heavier than the Beam. The same Principle has also furnished us with a Manner of dividing it, which is, to place first the sliding Mass, which I suppose, yet, to be a Pound Weight, at the Point c, where it can keep the Beam in Equilibrio

Fig. 12.

Equilibrio with the shorter Arm, then carry the Measure of the shorter Arm on the longer as many times as it can be contained in it, beginning the Numeration, not from the Point of Suspension, but from the Point of the Equilibrium c. The sliding Weight being stopt successively in 1, 2, 3, 4, 5, &c. should necessarily equiponderate with one Pound put on the Hook, then with 2, 3, 4, 5, &c.

The Division of the Rod in the present Hypothesis, runs still upon the same Principle. Let us suppose, that the Distance from the Point of Suspension to the Point c, is the fourth Part of the Length of the short Arm. Let us farther suppose the Excess of the Weight of the short Arm, over the Weight of the long Beam, to be as a real Weight suspended at the Hook. It is evident that this Weight should be a Quarter of a Pound, for this Weight is a Quarter of the Pound c, as the Distance of the Pound c from the Suspension is one Fourth of the Distance of the Hook from the same Point. If we imagine the Excess of Weight of the shorter Arm over the longer, as a Weight superadded to two Arms equal in Weight, let us put that Excess in some other Point, without moving the sliding Pound from c. In suspending by Imagination a Weight at three Fourths of the short Arm towards the Suspension, it may be asked, what will this Weight be? I answer, It ought to be one Pound; for the Weight is reciprocally to another Weight, as the Distance to another Distance; but the Weight in c is distant from the Suspension, one Fourth of the short Arm, as the exceeding Weight sought, being here at three Fourths of the shorter Arm, is only one Fourth distant from the Suspension. There is therefore Equality of Distances and Equality of Weights, that is to say, one Pound on each Side.

If we imagine the Excess of the lesser Arm over the longer, as a Weight suspended in the Middle of the short Arm, what will that Weight be? I answer, It will be half a Pound, half of the Weight c; as the Distance c is half of the Distance from the Middle of the short Arm to the Suspension. If we imagine the Excess suspended at the first Fourth of the shorter Arm, it will be one Quarter of a Pound, and one Third of a Quarter, which together make one Third of a Pound: Since the Distance of this Weight from the Point of Suspension being triple that of

c, it

c, it ought to be but one Third of the Pound that is in c. If, laſtly, conceiving the two Arms as equal, and leaving the Pound in c, you would have the Equilibrium by applying a Weight to the Hook, what will that Weight be? I anſwer, It will be to the Pound as the Diſtance c is to the whole Length of the ſhort Arm. That Diſtance is one Fourth of the ſhort Arm, therefore the Weight ſuperadded to the Hook, in order to make an Equilibrium, will be one Fourth of a Pound.

Thus it appears, that in what Point ſoever of the ſhort Arm we imagine the Poſition of the Exceſs on the Weight of the Beam, it will always be certain, that when the ſliding Weight balances the Beam at any Point, as at c, the right Counterpoiſe of the Exceſs of the ſhorter Arm over the Beam is found, and there is nothing more wanting afterwards, than to carry the Length of the ſhorter Arm on the longer, as many Times as it can contain it. There will therefore be four Quarters on the Hook, the Pound Weight being in 1, the firſt Diviſion from c; ſince the Weight is then to the Weight as the Diſtance is to the Diſtance; the Diſtance of the Diviſion 1, from the Suſpenſion, compared with that of the Hook from the ſame Point of Suſpenſion, is, as 5 to 4; likewiſe one Pound at the Hook with the Quarter of Exceſs, which we imagine ſuſpended at the ſame Hook, is with regard to the Weight in c, as 5 to 4. There will therefore be one Pound of Goods at the Hook, when the ſliding Weight comes from c to the firſt Diviſion 1. This Precaution once taken, all the reſt follow; when the running Weight comes to 2, there will be two Pounds of Goods at the Hook, when it comes to 3, 4, 5, there will be on the Hook 3, 4, 5, or 6 Pounds of Goods.

If the Exceſs of the Weight of the ſhort Arm, being conceived, not as faſtened to any Point of the ſhort Arm at Pleaſure, but only as hung at the Hook, ſhould be half a Pound; the Point c, where the moveable Weight, when ſtopt, would balance this Exceſs, wou d evidently be diſtant from the Center of a Length equal to half that of the ſhorter Arm: After which, the Numeration would go on by repeating the whole Length of the ſhort Arm. If, on the contrary, the Exceſs were but one, two, or three Ounces, the Point c would be diſtant from the Center, only

one

one, two, or three Sixteenths of the Length of the short Arm.

These various Divisions are no Trouble to any one but the Artist. When the Instrument is approved, and made Use of in Trade, let the Numbers 1, 2, 3, 4, 5, &c. begin from any Point whatever, the Buyer is directed by the Marks, without any Difficulty, and, most commonly, without any Fear of being defrauded.

However, it must be allowed, that notwithstanding this Instrument is more commodious in many Respects, yet, on the other Hand, it is more difficult to adjust, and more liable to Deceit, than the common Scales, or Balance with equal Arms: The great Number of Divisions which must be marked along the Beam, and those Marks being very near each other, may occasion many Blunders, and disorder the Mechanism thereof. The Points of Division must be of a certain Breadth to be discerned. The Seller, thro' Fraud or Mistake, may stop the Cursor, or sliding Ring, of the moveable Weight, not exactly in the Middle of the Point, make it declining on either Side, and the Fault, if often reiterated, may cause an Error, either in what we deliver out, or what we buy.

The long Arm, or Rod of the Stilliard, carries two Divisions on its opposite Sides, and these two Sides answer to the two Distances from the Hook to the Center. One of them is called the strong, the other the weak Side. The weak Side is used for Commodities of no considerable Weight, and answers to its greatest Distance from the Hook to the Center: Its Divisions, therefore, are at a greater Distance from each other, as far from each other as possible. The strong Side serves for the most ponderous Goods; and as on this Side, the Distance from the Hook to the Point of Suspension is less, the Marks of the Divisions are accordingly closer.

The two first Uses of the Swipe, or Lever, are, as we before observed, to lift up, and counter balance; but this Instrument, however, notwithstanding its great Simplicity, has been applied to divers other Uses, the bare Mention of which will be sufficient.

Two Levers fastened together in the Form of a Cross, by Means of a Rivet, which traverses them, and round which each by itself makes the Swipe, have formed For-

ceps and Pincers of all Sorts. Each of these Levers is, as it were, divided into two Arms by the Rivet; one of which must rise when the other falls. When two of their Arms are opened or separated on each Side the Rivet, which is their common Prop, the other two, tho' they move in a contrary Direction, separate likewise; then join each other again, when the others close. Let us call anterior Arms those we take in our Hand; and posterior those that are beyond the Rivet. The longer the anterior are, the posterior will act with a greater Strength. If, for Example, the anteriors of a pair of Pincers are six Times longer than the posteriors, there needs only to apply a Strength of ten Pounds, of which a young Boy is more than capable, to give to the Extremity of the posterior Arms a Power equal to he Action of threescore Pounds. By this Means a Block may be managed with all the Ease imaginable, which otherwise could scarcely be moved. And if a Man, whose Muscles can furnish an Action of the Value of 45 or 50 Pounds, will move, or fix, at his Pleasure, a heavy Piece of Metal, by laying hold of it with a Pair of Pincers, whose anterior Arms are six Times longer than the posterior, he exercises on that Mass a Strength which is like, or equivalent to a Weight of 300 Pounds.

This new Instrument, so proper to lay hold of heavy Weights, and conquer Resistances, may be diversified *in infinitum*. It acquires new Names as well as new Faculties, according to the different Forms given to its posterior Arms. One of the most useful is, to have rendered them sharp, and made Scissars, or Forceps, and Sheers of them, the Strength whereof increases with the Length of the anterior Arms: they can be such, as they may be used to cut Lead, Copper, Iron Plates, or other still harder Matters. The Strength of the posterior Arms increases, likewise, in Proportion as the Substances to be cut are applied nearer the Rivet. For it is the same as if those Arms became shorter; and we have seen, that the Strength of the posterior Arms increases in Proportion as they are shortened; because the moving Power that acts on the Anteriors, is so much the greater, as they exceed the others in Length.

The Lever stopped at one End.

There is a very advantageous Manner of using the Lever, which appears quite different from the preceding ones, and where,

notwithstanding, the same Progress of Strength can be observed; and that is, by fastening one End of the Lever by a Staple, or Hook, so as to keep it from slipping, and yet in such a Manner, that the Lever may rise, or fall, in it's whole Length. Now, let us consider three Points in this Lever; 1. The Point of fastening, which props one End of the Lever. 2. The Point of Resistance, whereon the Lever is lowered. 3. The moving Power applied at the other End of the Lever. All the Action of this Lever falls on the Point of Resistance, and the nearer this Resistance is brought to the Point of fastening, the greater is the Extent given to the Arm that grows longer from the Point of Resistance to the moving Power; which moving Power, though always the same, becomes more active, in Proportion as this Length increases. In this consists the Strength of the great Press; which is a large Tree, or several Trees combined together; one End whereof is firmly fixed in Clamps. These Trees are laid on a Heap of Grapes, pretty near that same End. But at the other End, which is at a great Distance from it, a large Case, filled with Stones, to the Amount of twenty thousand Weight or some other Power, is made to act, which presses the Cakes of Grapes with so much the greater Facility, as that Cake is nearer the Staple, and more distant from the Power.

If a Lever be placed by one of its Ends on an Iron Pin, which keeps it steady, and that Lever be sharpened like a Knife; a Loaf, or any other divisible Matter, serving of Resistance to that Lever, will experiment the Action thereof much stronger, as the Power will act at a greater Distance from the Prop, or that Prop will be nearer the Staple. Each Point of this Lever describes, at equal Times, so many different Arches. The nearer the Point is to the Staple, the less is the Arch, and, on the contrary, the most distant Point describes the largest Arch. All these Points which describe their different Arches, in equal Times, act still in an inverse Proportion of the Powers to the Spaces through which they run: so that the Power must be increased, in Proportion as the Arch it runs through becomes less; and there is less Force required, in Proportion as the Agent describes a greater Arch. Suppose the Point of the Knife brought on the Bread, to be 5 Times nearer the

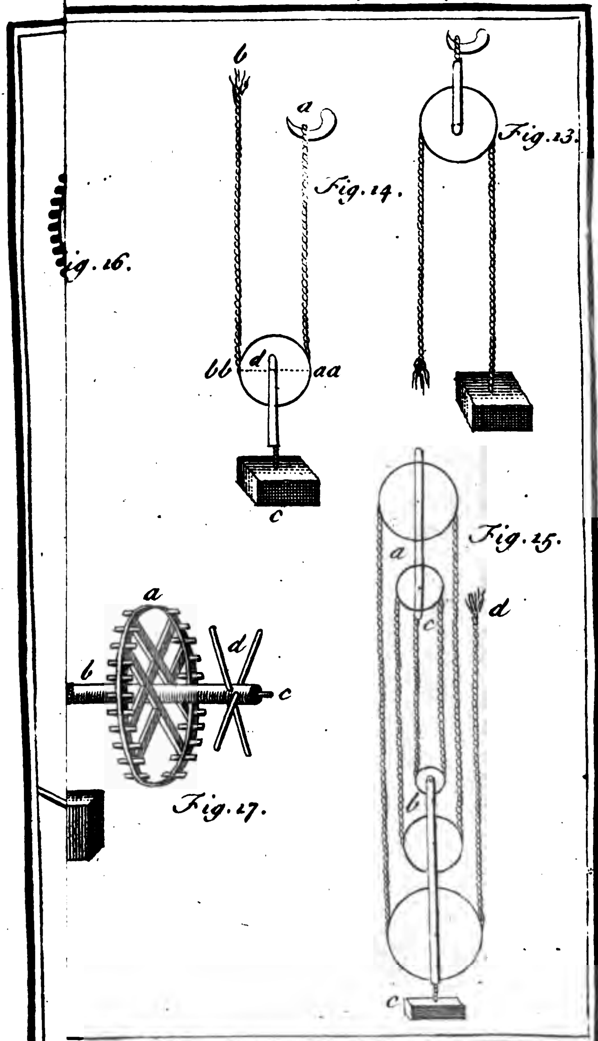

b
a
Fig. 14.
bb
d
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Fig. 13.
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Fig. 15.
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c
Fig. 17.

Staple, than the Hand that lowers it, that Hand describing an Arch 5 Times greater than the cutting Point, if the Effort it makes, be equal to the Pressure of ten Pounds, the cutting Point acts with an Effort of 50: and if the twenty thousand Weight, hung at the Beams of the great Press, is 5 Times more distant from the Heap of Grapes, than that Heap is from the Point which stops the other End of the Beams, the Point of Pression, by traversing five Times less Space than the Weight, presses the Grapes with an Effort equivalent to one hundred thousand Weight.

Whether a Lever, stopped by a fixed Point, be lowered or raised; whether we use it to press a resisting Matter, laid between the fixed Point and the Power; or to raise a Weight hung between the Staple and the Power, the Advantage is the same, and the Rule the same; *i. e.* that in all these Cases, what the lesser Space run through is to the greater, the moving Power is to the Resistance. Now, the nearer the Resistance is to the Staple, the less is the Space run through by that Resistance: and therefore the moving Power is less in Proportion, but then its Weakness is compensated by the Space.

Plate V.

The first and most common Uses that were made of the Lever, were to weigh, press, cut, remove any ponderous Body. The most advantageous was, doubtless, the removing, by that Means, very heavy Weights; it was not sufficient, however, to move them only, since it was absolutely necessary, that sometimes they should be raised: and it was by that Means only, that Man could rectify the Inconveniences of an uneven Ground, and build his Houses to any Height rerequired.

The Pulley.

The Parts of the Pulley are the Block, the Wheel, or Rundle, and the Axis. The first is that Piece which contains the Wheel, to which it is fastened by the Axis that is drove through the Block, and a Hole in the Center of the Wheel; so that the Wheel may turn freely round either Way. The Wheel, either of Wood, or Metal, has a Channel round its Circumference to receive the Rope. The Axis is a Pin which traverses the Rundle, and round which as many Points it ascends on one Side, so many it descends on the other. The Pulley is made use of two different Ways. It is

sometimes fixed, and sometimes moveable. It is said to be the former, though the Wheel turn round the Pin, whenever the Block is fixed and immoveable (*Fig.* 13.) The Pulley is said to be moveable, when the Block is not fixed to one Point, but follows the Direction of the Weight that is hung to it (*Fig.* 14.) The fixed Pulley is a true Balance, which must be demonstrated. The moveable Pulley is a true Lever likewise, but we must shew the Advantages that attend it. The fixed Pulley is a true Balance, because one may conceive each Point of the Wheel at the Extremity of a Line, or Radius, terminated at the Pin, and corresponding with a like Line on the other Side. The two Lines, or Radii, make together, two Arms, or the Equivalent of the Beam of a Balance. But the Beam must be taken horizontally, if we would form a true Judgment of the Equality of Weights. Likewise, in all the Points which compose the Wheel of the moveable Pulley, we need only regard the two Extremities of the Line that crosses the Wheel and Axis: because these are properly the Points which receive the Pulsion of the Powers, and which may be considered as prolonged by Means of Ropes, and immediately applied to the two Ends of the Line that cut the Point of Suspension. When we will raise a Burden by the fixed Pulley, we run a Rope over the Wheel, and of the two Ends that hang down in parallel Directions, one supports and raises the Burden, the other is directed the contrary Way, by the Power which acts upon it, to make the Burden ascend, while it descends itself.

When an Agent, or Power, supports a Weight, by the Help of a fixed Pulley, he is obliged to act with a Force equal to the Weight: for if Lines are drawn from the Center to the Place where the Rope leaves the Pulley, those Lines will be horizontal, and, at the same Time, perpendicular to the Rope; they will measure the Distances from this Center to the Directions of the Power, and of the Weight. Now these Lines, being perfectly equal, supply the Want of a Lever with equal Arms, whose Extremities describe equal Arches. The Spaces, therefore, run thro' by the Powers, being the same, the Sums of the Efforts of those Powers will likewise be the same, and it suffices to make the Power over-balance the Resistance, that it turn the Scale but never so slightly.

The

The fixed Pulley is not only made use of to raise Burdens, by the Conveniency of a Counterpoise, but to change also, as often as Occasion requires it, the Direction of the Powers, and hinders the Rope from wearing off.

Let us now see whether the moveable Pulley be not more serviceable to the Power, than the fixed Pulley. This last is a Balance, whose horizontal Line describes by its Extremities equal Arches. But the moveable Pulley is a Lever, one of whose extreme Points is supposed immoveable, and all the rest describe unequal Arches. The whole Advantage must be for the Power fastened to that Point, which traverses the greater Space, which Advantage must be measured.

It must be observed, that one End of the Rope is fastened to an immoveable Hook a, and the Power pulls the other End b. So that all the Points of the Rope fastened to the immoveable Hook, serve to support the Pulley; and because the Weight c, is between the Power b b, and the Support a a, it is necessary, to act with Advantage, that, in the Equilibrium, the Powers should make an Effort weaker than the Weight; for in reality, the Rope a a, fastened to the Hook a, supports Part of the Weight c. It is certain therefore, that the moveable Pulley facilitates the Action of the Power C, and that the same may be supported by it with a less Effort than what is required with the fixed Pulley. But if we consider as a Lever, the Line a a, b b, which cuts or unites the Points, where the Ropes press, or quit the Pulley successively; will it not be evident, that the Direction of the Power b b will be twice further from the Support a a, than the Direction of the Weight c, which we ought to conceive as acting in d? Therefore, according to the stated Rule for the Lever, the Power b b should act with half the Power of the Weight c: the Measure of this Effort is found in the Comparison of the Spaces run through.

Fig. 1.

Now, since the Power b has begun to raise the Weight, till it arrives over-against the Hook a, it is found to have traversed the whole Space from the Ground, or Floor, to the Hook a, whilst the Weight c has traversed but half that Space; and when the Weight will be arrived at the Hook a, the Power b will have run not only through the Space from the Floor to the Hook a, but likewise another

such Space above the Hook. If therefore the Powers are less in Proportion, as they are oftener repeated, the Space run through by the Power b being double that traversed by the Weight, there is but half the Power wanted to be in Equilibrio with the Weight.

In the Use of the fixed Pulley, the Power moving according to its own Direction, makes the Weight move contrary to his, by Means of a simple Equality, with a very little Superiority. Raising of a Burden against its natural Direction, is, then, the sole Advantage gained.

In the Use of the moveable Pulley, we not only raise the Burden, but do it with half the Strength; which is a new Advantage. Having but a small Share of Strength, let us endeavour to husband it still better, and that even by increasing the Profit resulting from it; the Merit, and Processes of Mechanics being like those of Œconomy.

Combined Pulley, *Fig.* 15, 16.

There are many Instances wherein a Man may have occasion to remove or raise heavy Masses, whose Weight vastly exceeds the Strength of his Arms, and even the usual Helps and Assistances that he receives from the Lever, or the moveable Pulley. He cannot therefore conquer these Resistances, but by joining together several Levers, or several Pulleys, to multiply the Helps he can receive. His combined Pulleys must not be all fixed; for if they were, they would rather obstruct than forward his Design. Neither must they be all moveable, because the moveable want good Supports.

Moufles.

In order, therefore, to render the Combination of the Pulleys profitable, he joins the fixed with the mobile, and that Combination borrows in the Mechanics the Name of Moufles. The Combination of moveable Pulleys, is called Moveable Moufles, and that of fixed Pulleys Fixed Moufles. The fixed Pulleys are all inclosed in the same Block as (*Fig.* 15.) and the moveable Pulleys in another Block, as b, in the same Figure. Both these sorts of Pulleys may be united in two different Manners: First, All the fixed Pulleys may be traversed by one same Pin a (*Fig.* 16.) in the same Manner as the moveable Pulleys by the Pin b, (*ibid.*) Secondly, Each Pulley may have its own Pin. One End of the Rope is generally fastened to the fixed Pulley, as c (*Fig.* 15.) and

a (*Fig.*

a (*Fig.* 16:) then the Rope runs alternately under one of the moveable Pulleys, and over one of the fixed, and so on over all; and the other End of the Rope is held by the Agent, or Power, in order to pull and raise the Burden.

Let us now consider, of what Succours this kind of Pulleys are to the Agent. Suppose an Oilman wants to take out of his Celler a Tun of Oil, or any other Commodity, of 5 or 6 hundred Weight, let him have only a Set of fixed Pulleys placed over the Hole made in the Roof of his Cellar, and another Set of moveable Pulleys fastened to the Vessel, and two Servants only will be able to draw it up. If they are able, as no doubt they are, to lift 50 Pounds each, their combined Strength will lift 100 Pounds: Now let them only make use of a Block with three Pulleys, they will not only make Equilibrium with a Tun of Oil of six hundred Weight, but even raise it as easily as a hundred Pounds Weight, from the Bottom of the Celler to the Top. That the Force, or Power, of one hundred and few Pounds will lift up six hundred, may be demonstrated by the Principle already mentioned. Suppose the Weight ascends one Foot, it is necessary that the Rope, which encompasses the six Pulleys, and make each of them revolve once the Length of a Foot, should shorten by six Feet in the Hands of the Person that pulls it; which is the same, as if the Hands had traversed the Space of six Feet, while the Tun of Oil is traversing the Space of one Foot; but in the Equilibrium, the Powers and the Weights ought to be in an inverse Ratio of the Spaces, which the Power runs through according to its Direction, and the Weight against its own Direction. The Action, therefore, of the moving Power which runs through six Feet, whilst the Resistance moves only through one, ought to be but one sixth Part of the Weight, to keep an Equilibrium. Thus, when the Load weighs six hundred Pounds, it suffices, that the moving Power should make an Effort of 100 Pounds; since 100 Pounds, with a single moveable Pulley, is equivalent to two Hundred. If there were four Pulleys in each Block, the Rope which encompasses four fixed, and four moveable Pulleys would slip through eight Feet, while the Weight is traversing one. It would suffice, therefore, that the Rope should make an Effort equal to an eighth Part of the Resistance; and the Action of a Man's Arms, or of a Weight

of 100 Pounds, only adding 2 or 3 Pounds more to it, will raise eight hundred Weight. The Rule therefore, for finding the Proportion of the Power to the Weight, is to double the Number of Pulleys in the moveable Block, and there is the same Proportion between the Power and the Weight, as between Unity and double the moveable Pulleys. In all that has hitherto been said concerning the Pulleys, we have supposed the Directions to be parallel, but if we were to deviate from the Parallelism, by making them to concur together, the Advantage accruing to the Power from the Pulleys would be somewhat less than that we have determined; because, in this Case, the Strength of the Power would be divided, by drawing the Weight partly upwards, and partly towards that Part to which it inclines.

Wheels of Carriages.

The Wheels of Carriages partake, in some measure, of the Nature of moveable Pulleys; the Ground where the Wheel rests or stands, is the Point of Support: The Length of the Lever is taken from the Ground to the Nave of the Wheel, which answers to the Beam where the Horses are tied. Large Wheels, therefore, are more commodious than small ones, because their Levers are longer, and each Point of the Nave, which is drawn every Moment, is found in the Direction of the Traces and at the Height of the Breast of the Horses that draw the Carriage.

There are *Roman* Medals, and other ancient Monuments, that represent the Vehicles of the Empresses, and other Sorts of Chariots. These Vehicles have four Wheels, of the same Height and Breadth; and therein the Ancients seem to have been better served than us Moderns, who put to our Coaches and Waggons, two very high Wheels, and two others very low ones: Whence it follows, that the Horses draw at the same time the large Wheels by a long Lever, which is at their Height, and the small ones by a short Lever, much lower than the Wheel itself, not only the Lever of the little Wheel is short, but the Direction of the Trace does not seize the Extremity thereof at the Perpendicular, which renders it less serviceable. The Shortness of the Lever, in the little Wheel, is not all the Deficiency; if we calculate either on the most probable Hypothesis, or on precise Measures, the little Advantage got by

by means of the short Lever, and the superior Advantage they gain from the greater, which is the perpendicular Radius of the great Wheel, one may reckon at a Medium between them, and that will give us the exact Totality; but this Totality of Succours would be much greater, if our Carriages were to roll on four equal Wheels, *i. e.* by the Help of four long Levers riveted at their Extremity in a perpendicular Direction of the Trace; not only the Radius of the little Wheel, and the Direction of the Trace, cause here a Diminution of Profit; but even the Horses are loaded, by this oblique Direction from Bottom to Top, with Part of the Weight of the Vehicle. Has this double Inconvenience been introduced without any Design? No; the Intention of the modern Method seems to have been, to keep the fore Part of the Carriage in a kind of Suspension in a bad Road. The first Effort of the Horses may lift up that fore Part of the Vehicle, and so facilitate the disengaging the other Part. Let us now recapitulate, in a few Words, the Advantages procured from the Pulley and the Lever. With the common Levers, whether they are divided into two Arms by a Prop, or fastened at one End, any Burdens may not only be moved, but lifted up: but then they cannot be moved by them through any large Space. With a fixed Pulley, they may indeed be drawn up to any Height at Pleasure, but the Agent must act with a Power equal to the Weight, and even somewhat more, to carry off the Equilibrium. With the moveable Pulley, it is true, this Resistance is diminished by half: And if the Number of Pulleys be increased, the Power gains twice as much Strength as there are moveable Pulleys: So that the moving Power ought to be to the resisting Weight, as one is to twice the Number of moveable Pulleys. But this Multiplication of the Pulleys, so advantageous in many Cases, becomes, notwithstanding, troublesome, and even impracticable in others. Men have therefore attempted to reunite, in one single Machine, the Advantages of the two former, and have succeeded.

The Wheel and its Axletree, *Fig.* 17.

Two fixed Pulleys have been joined together, one very large, a, and the other very small, b; and traversed by the same Axis, c c. The Rope that draws up the Weight is to be wound round the lesser Pulley, b: And the Action

 of

of the moving Power to the Circumference of the great Pulley. a. The great one is called the Wheel, the lesser the Role or Cylinder; and as the Cylinder may be lengthened at Pleasure, so may the Breadth of the Wheel be increased in the same Manner. There may be several Spokes drove through the Fellows of the Wheel, to help the Action of the moving Power on the Wheel, as in a, *Fig.* 17. This Wheel may be made wide, in the Shape of a large Drum, and capable of receiving within its Circumference one or more Men, who by advancing forward in that Drum, will determine each Part they trample upon to descend, and which being continued, makes the Wheel, the Cylinder, and the Rope, turn round. This Machine is called a Calender, or rather Tympane, c, *Fig.* 18.

The Tympane.

Instead of a Wheel, it may suffice to make Holes in the Cylinder, to which Spokes, or Radii, are fitted, which the moving Powers lays hold of as so many Levers, to make the Machine turn round. The Pulley b, which is called the Cylinder or Role, occupies a considerable Length to the Right and Left of the Circumference of the Wheel, a. It may be conceived traversed through its whole Length by a Line, or Axis, the two Ends whereof, c c, are called Pivots: These Pivots support the Machine; on them it makes its Revolutions; they ought therefore to be very firm, that the Motions may be regular and steady? The less they are, the less will the Friction be, and the less will the Revolution be retarded. They may likewise be considered as the Pin of a Pulley, and the Fulcrum on which they turn, as supplying the Place of a fixed Block.

The Role. *Fig.* 17.

After this Description of the Wheel and Role, let us consider its Use. We here find the Advantages of the Lever and Pulley, and in the mean time avoid the Inconveniences of both.

The horizontal Radius of the Wheel, by descending on one Side, raises on the other the Radius of the Role where the Rope is fixed. The Axis that traverses the Wheel and Role is therefore a true Point of Support: And these two Radii together perform the Office of a Lever. The Radius of the Wheel is its long Arm, and the Radius of the Role its shortest. But the Use of the common Lever is slow,

slow, and full of Obstructions; whereas the Action of the Lever abovementioned is continued without Interruption by another Lever, because the Power being pulling continually the same Way, causes the Weight to rise higher and higher in a contrary Direction. These Radii measure likewise the Distances from the Axis to the Direction, that is, to the Circumference of the Wheel where the Power acts, and to the Point of the Circumference of the Role where the Resistance is made. Therefore, in the Equilibrium, the Power is to the Weight, as the little Radius, or Radius of the Role, is to the Radius of the Wheel. If the Radius of the Wheel is ten times longer than that of the Role, the Strength of the Power need be but one Tenth of the Resistance. Thus, if we suppose the Strength of the Power equal to 50 Pounds, it will keep in Equilibrio a Weight of 500.

Now the Effort of the Power being thus ten times less than the Resistance, the Power must, in Return, run thro' a Space ten times greater than that run over by the Weight, since the Weight ascends no faster than the Point of the Surface of the Role ascends, and the Circumference of the Wheel is ten times greater than that of the Role round which the Rope is wound. The extreme Points of the horizontal Line, which the Rope successively seizes and binds close, are the Measure of the Space that the Weight runs through. Now at every Point run through by the large Circumference, the Power must act with the Strength of 50 Pounds, in the same Manner as the Weight makes the Resistance of 500 Pounds at every Point of the Space it rises through; which renders the Sum of the Efforts of the Power equal to the Sum of the Resistance which the Weight opposes to it. For the Power necessarily runs thro' ten Points whilst the Resistance runs through one: But the Strength of 50 Pounds, ten Times repeated, or multiplied by ten, give equally the Product 500, as the Resistance of 500 Pounds multiplied by one.

When the Role, instead of having a Wheel, is only supplied with Bars, the Length of these Bars will not always measure the Distance from the Prop to the most advantageous Direction of the Power. This only happens, when the Direction is perpendicular to that Length or Distance; as may be seen in the Advantage found by one that draws

up Water from a Well, when the Bow which he depresses to make his Pail ascend is horizontal, the more the Extremity of that Bow is depressed, the more the Direction approaches the Prop. Now the Advantage diminishes in Proportion as the Direction draws near the Prop: Therefore we see that the Person that draws the Water, pulling still harder, and adding often the Impulsion of his Knee on that Bar, to the Motion, he begins to give with his two Arms to the next Bar. The Machine we speak of can have its Cylinder leaning on a Level, or placed horizontally, and then it is called a Role. If the Role be perpendicular to the Horizon, the Machine is called Draw-beam and Capstane.

The Crane. Fig. 18.

We not only have Occasion to remove and raise Burdens; but when they are arrived at the Height desired, we must transport them from one Place to another, which, according to the Nature of the Place, is sometimes very difficult. The Machine has been appropriated to that Use, by dividing it in two Parts, one whereof is a firm Support or Prop, and the other, an Arm to turn round, and equally proper to raise a Burden to a great Height, and then transport it by turning freely, all Ways, into any Point of the Circumference we want to place it. This Arm, that thus raises and stretches out any Way, like the Neck of a Crane, has given the Machine the Name of that Bird.

On the Base 1, raise a large Beam, kept upright by the Props, and terminated in the Form of a Bodkin 4, which is the whole Support of the Machine: The other Part, which is moveable, contains, First, the Neck A, furnished and traversed in its whole Length with Pins, which serve as a Ladder to give Access to all the Parts of the Machine; Secondly, the Drum C, with its horizontal Beam B; Thirdly, the Brace D, and the main Brace E, bored to encompass the pointed End of the Beam 4, in such a Manner as to turn round easily with the whole Mechanism, whilst the Support only remains immoveable. The Rope unwinds off the Role B, and runs over the Extremities of the three Braces D, is brought from thence to the End of the Neck A, whence it descends to be tied to the Load F. It meets in D and A, at the End of each Brace, and of the Neck, with as many Pulleys; which indeed add nothing

thing to the Power, but only facilitate the Passage of the Rope, by supporting it on movable Points, that cause but little Friction; for the Number of Points that rub the Rope is but small, and then they part from it every Moment.

Several Men enter the Drum of the Wheel, and go forward by ascending the Inside of the concave Circumference. Their Weight has almost as much Power, as if it was suspended in a perpendicular Direction at the End of the horizontal Radius, and by depressing continually every Radius, which succeed each other in that Situation, they raise the opposite Radius of the Role. The End of every Radius carries up, in ascending, the Point of the Rope that lies upon it; and as many new Points as ascend off the Surface of the Cylinder, so many Points does the Load go through in ascending. When it is arrived at the Height desired, the Wheel is stopped. This Wheel is like the Tail of the Crane, and the End A is as the Bill. The Tail, or posterior Part of the Crane, cannot be turned one way round the Nut 4, but the long Neck and Bill must move with it in a contrary Way: And these two Parts being in a kind of Equilibrium, the Load will be carried round with the Crane that bears it: Then with a few Turns of the Wheel, contrary to the preceding, the Load is carried exactly to the Point desired.

But what is the Expence of Power required here to raise the Load? The whole Weight is felt at the extreme Point of the horizontal Radius of the Cylinder, or Axle-tree of the Wheel B, and the Men in the Cavity of the Tympane endeavour to raise that Point. If they raise it, they raise the Weight; if, therefore, the moving Power, and the Weight raised, are in an inverse Ratio of the Distances of their Directions from the Axis, which is the Support, there is Equilibrium. Let us place four Men in the Tympane: They may weigh together about 600 Pounds; which six hundred Pounds are as perpendicularly suspended at the End of the horizontal Radius or Spoke.

If the End of each horizontal Radius of the great Wheel be successively lowered in a Direction six times more distant from the Axis than the Direction of the Weight, those Men will equiponderate a Weight five times stronger than they; they will be able therefore to equal and conquer a three thousand Pound Weight; for if the Effort which

which results from their Weight, acts on the Wheel at the Distance of five Feet from the Axis, it is the Value of six hundred Pounds, which will act five times, while the three thousand Pound Weight, at the Distance of one Foot from the Axis, acts but once; but an Action or Impression of three thousand Pounds is the same as five Actions or Pressions of six hundred Pounds. The Sum of the Efforts made by the small Power in the great Tract, is equal to the Sum of the Resistances which the great Weight oppose to it in the small Tract: Whence results always this great Principle of Mechanics, That when the Power and Weight are in an inverse Ratio of the Spaces over-run, or of the Distances of the Directions from the Prop, there is Equilibrium: And where there is Equilibrium, the least Strength superadded to it gains the Victory.

The Wheel, and its Pinion, *Fig.* 19.

As the Multiplication of moveable Pulleys facilitates the Action of the Power, and diminishes the Action thereof, the Combination of several Wheels, with their Spindle, can produce the same Advantage, if a Wheel be driven by the Spindle of another. To perform this, the Spindle of the first Wheel, and the Circumference of the second must be notched. If the Spindle of a Wheel be notched on its Surface, into several Curves or Teeth, and the Circumference of another Wheel be divided into a certain Number of semblable Teeth, the Teeth of the second Wheel cannot be inserted into the Teeth of the Cylinder of the first, without driving one of them by the Motion of the other. The Insertion of a Wheel into the Curves of a Spindle, is what we call Implicating a Wheel. The Spindle or Arbor, thus notched into a certain Number of Teeth, is called a Pinion. If the Spindle be of some Length, and has, instead of Teeth, a certain Number of Channellings, in the Form of Rods, terminated by two round Plates, those Rods, as well as the Teeth, can receive the Impulsion and Implication of the Teeth of a Wheel. Such a Spindle, or Arbor, changes then its Name of Pinion, into that of Nut or Lanthorn. Several Wheels playing thus by the Assistance of a Lanthorn, or Pinions, are what we call Wheel-work. The Cylinder of the last of those Wheels, thus combined together, is without Teeth, 3, and receives the Rope to which the Weight to be raised is fastened.

Pull

Pull with the Power 5 the Wheel 1: The Pinion of that Wheel moves, in ascending, *Fig.* 19. on the Side of the Wheel 2. It drives the same way the Teeth of the Wheel. This, therefore, together with its Pinion, moves, in descending on the opposite Side, *i. e.* towards 3. The Teeth of the Wheel 3 driven by the Descent of the Pinion 2, cannot descend on the Side 3 without making the contrary Part ascend, since it is always the Application of the Principle of the Lever. Therefore the Arbor of the Wheel 3 ascends, and winds up the Weight 4. The Power 5 pulls and ascends, according to its own Direction: The Weight 4, on the contrary, ascends against its own Direction, with the Advantage of that displacing. Can the Mover find here any Diminution in the Example of the moving Force, and which is the Rule of that Profit?

The Force of the moving Power is to the Weight as the Space passed over by the Weight, is to the Spaces passed over by the moving Power. If the Resistance, the Weight 4, has over-run a Fathom, while the moving Power 5 unrolls a hundred Fathoms off of the Wheel 1, there will be but one Pound in 5 wanting to make Equilibrium with a hundred Pounds in 4.

The Engineers are at Liberty to multiply the Pieces of the Wheel-work, and proportion the Leaves of the Pinions to the Teeth of the Wheels, according to the different Calculations, and diverse Advantages they propose to themselves. We will be contented here, to assemble three Wheels; and give the Pinions of the first and second, and the Arbor or Spindle of the third, a Radius of 3 Inches; to the three Wheels, a Radius of 30 Inches; and sixty Teeth to the two dented Wheels: By this Proportion will be sufficiently understood the Rule which makes the other Dispositions succeed.

It is very true and evident, that the Force of a Pound, and some Ounces, can wind up a thousand Pound Weight, provided it passes over a Space a thousand times greater than that the Weight runs through, and repeats at each Point the Effort of one Pound, and a little more, against the Weight. By that Means the Sum of the Efforts it has made in its Way, is found equal to the Sum of the Resistances, it is what we must compute by the Disposition of the Wheels, 2, 3, *Fig.* 19. The

The Radii of the Pinions of three Inches being, with their Circumference, but one tenth of the 30 Inches of the Radii of the Wheels and their Circumferences, while the Wheel 3, and its Arbor, make a whole Revolution, the Pinion of the Wheel 2, and that Wheel 2 will make ten Revolutions. For it will be but after the tenth Revolution, that the Pinion 2, which with its six Teeth cannot drive more than six of the Wheel 3, shall end meeting with all the Teeth of this last; ten times six making up sixty. The Wheel 2, in its ten Revolutions, will have exhausted also, in each Revolution, ten times the six Teeth of the Pinion 1. If to make one Revolution the Wheel 2 requires ten in the Wheel 1, this must make ten times ten, or a hundred Revolutions, while the Wheel 2 makes ten, and the Wheel 3 one; so that if the Power was applied on the Pinion of the first Wheel, it would pass over a Space a hundred times greater than that over-run by the Weight: But as it is applied to the Circumference of the Wheel, which is ten times greater than that of its Arbor, it will pass over a Space ten times greater, and consequently a thousand times greater than the Space over-run by the Weight. Now the Proportion of the Spaces over-run establishes the inverse Proportion of the Powers: Therefore if the small Power runs a thousand times swifter than the greater, a Child, with the Force of one Pound, and some more, will raise a Tun of Water weighing a thousand Pounds.

The Jack, *Fig.* 20.

The Profit arising from the Wheel-work, has engaged Men to make diverse Applications thereof, equally useful. Hence all kinds of Mills, Jacks, Reels, and other Machines. One of the most commodious, and best contrived for unforeseen Cases is the Jack. It consists of a Box two Foot long, six Inches broad, and four thick, and containing a Wheel-work composed of the following Pieces. Nothing appears on the Outside of the Box but a Handle, which makes an Elbow, placed near the Top of one of the large Sides of it, and a dented Blade which comes out at the Top. The Handle is fastened, Inside, to the Center of a Pinion 1, which has but four Teeth, which catch the Teeth of a Wheel 2, to make it turn round. That Wheel carries another Pinion of four Teeth. An iron Blade 3, dented in the same Man-

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ner throughout the whole Length of one of its Sides, and leaning on the Wheel 2, presents its Teeth to those of the Pinion 2. When the Handle and its Pinion play, the Wheel and the second Pinion play likewise.

The Coachman of a Stage-Coach, and a Waggoner, never fail carrying this Machine along with them, the one in his Coach box, and the other in his Waggon. He may chance to have in his Coach, Ladies, or other Persons, without Strength and Dexterity. If one of his Wheels happens to sink into a Slough, or break, how shall he be able to lift it up, or make the Axle-tree enter the Nave of a new Wheel, without unloading his Carriage? He takes his Jack, and without any other Help, undertakes, with Success, to restore the Axle-tree and Carriage to their former Situation, either to roll, or receive a new Wheel, if it wants one. He places the Foot of the Box on a firm Ground, over a strong Piece of Wood: He first fixes the End of the Blade, which is a little hollow, and made in the Shape of a Half-moon, to that Part of the Axle-tree which is the nearest that which is broke. The Blade cannot come out of its little Lodge, without lifting up both the Axle-tree and Carriage; because the Handle cannot play without lifting up the Blade, and consequently all the rest. But where shall that Man find Strength enough to turn the Handle, and conquer such a Resistance? He could easily supply a Strength equivalent to a sixty Pound Weight: And here he only wants a Strength equivalent to thirty.

The whole Weight of the Carriage, which we suppose to be two or three thousand Pounds, rests, now, on the Blade, and is felt by the Pinion of the Wheel 2. Let us give to the Semi-diameter of the Pinion the tenth Part of the Semi-diameter of the Wheel: The Hand of the Power applied to the Circumference of the Pinion 2 would bear the whole Weight of the Carriage: But applied to the Circumference of the Wheel 2, he would feel already a Resistance ten times less; and then an Effort equal to the tenth Part of the Weight would be sufficient. But the Hand works on the Handle, which is, itself, longer than the Radius of the Wheel; that Hand, therefore, will not feel there but the tenth Part of the Resistance it would feel applied to the Circumference of the Wheel, if the Semi-diameter of the Pinion 1 be but the tenth Part of the Turn of the

the Handle: For the Hand on the Handle is ten times more distant from the Point of Support, than is the Circumference of the Pinion 1, implicated in the Teeth of the Wheel.

The Radii of the Pinions being here as the small Arm of the Lever, and the Radii, as well of the Handle as of the Wheel, making here the Function of the great Arm, the Weight which exercises a Resistance of a hundred Pounds, on the Blade 3, exercises but the tenth Part of a hundred, or a Resistance of ten Pounds, on the Teeth of the Wheel; and lastly, the tenth of ten, *i. e.* one Pound, on the Handle: Therefore the Hand of the Carrier has in this Case of a hundred Pounds resting on the Blade, but the Weight of one Pound to conquer, and the Force of one Pound to oppose to it. If the Resistance be of a thousand Pounds on the Blade, he will conquer it, by making a Force of ten Pounds to act on the Handle. He will feel but twenty under a two thousand Weight, and lift up three thousand Weight with thirty. If it was necessary to double this Effort, and oppose to the Resistance a Force of sixty Pounds, he will bring up even above the Level an Axle-tree loaded with a six thousand Pound Weight. Thus the Wheel, and all that is wanting to it, is restored; the Jack is put in his Place; the Coachman is neither tired, nor in a Heat; he mounts on his Seat, whips his Horses, and the Coach or Carriage rolls.

Now if we will examine the Resistance of the Weight, and the Force of the Agent on the Side of the Spaces overrun, we shall find that the Hand must run a hundred times swifter than the Blade which lifts up the Carriage. For if the Blade 3 lifts up one of its Teeth on a Tooth of the Pinion 2, the Space passed over by the one is the same as that passed over by the other. But a Tooth of the Wheel 2 runs ten times swifter, or passes over a Space ten times greater than a Tooth of the Pinion 2. Besides the Teeth of the dented Wheel runs no otherwise, than by being driven by so many Teeth of the Pinion 1; and, if there are twenty Teeth at the Circumference of the Wheel, the Pinion will not exhaust them but by inserting five times its four Teeth into them; while the Circumference will make a whole Revolution, the Pinion will make five. Now to implicate twenty Teeth once, or five times four Teeth, it is

is to over-run as much Space on either Side. Therefore the Spaces over-run by the Circumference of the Wheel 2 are equal to those over-run by the Pinion 1. But while the Pinion 1 makes five Revolutions, the Handle, which is ten times longer, will pass over a Space ten times greater: therefore the Hand that turns it will run ten times swifter than the Pinion 1, and the Circumference 2: But the Circumference 2 runs ten times swifter than the Pinion 2 and the Blade 3; therefore the Hand over-runs a hundred times more Space than the Blade and Weight. It is a Necessity, that where the Weight makes a Resistance of a hundred Pounds on the Extent of an Inch, the Hand repeats the Efforts of one Pound in the Extent of a hundred Inches. The Sum, therefore, of the Efforts it produces equal the Sum of the Resistances which the Coach opposes in a Tract a hundred times less. Whence a Hand, traversing three thousand Inches, makes easily Equilibrium with a Resistance which traverses thirty; if exercising easily a Force of thirty Pounds, which puts it in Equilibrio, with a Weight of three thousand, it adds one Pound, or a small Effort more to the Action of thirty; it conquers the three thousand so far as to raise them thirty Inches, or two Feet and a half, above the Ground. The Weight will ascend higher, if the Action continues.

The Wheel-work has been happily applied to an infinity of other Uses. It is applied to Mill-stones, Cylinders, and Hammers. It is used to grind Corn; to saw Wood, or Stone; to pulverize the Matters which enter the Composition of Gunpowder; to bruise the Bark of Trees, used to tan the Leather, and render it impenetrable to Water; to pound Plaister, to mill Cloth; to pound old Rags, and reduce them into Pap to make Paper of it; to flatten Metals; to bruise the Sugar-canes; and to several other Uses. The Principle and Successes of the Mechanics are found the same in all these Inventions; and though the Structure of the Machines be diversified without End, Man shews thereby, still better the Fecundity of his Views, and the inexhaustible Fund of his Dexterity, which consists, especially, in husbanding his Strength, conquering great Obstacles by a weak Action, and making often Beasts, and the Elements, supply his Place. While he minds his domestic Affairs, or takes his Rest, an indefatigable Horse,

or

or the Weight of the Air, or blowing of the Wind, or Fall of a running Stream, or even Fire itself, drives its Pump. He finds, at his Return, or his Pond full, or his Corn ground, and ready to be made into Paste. All the Hurly-burly of the great Cities or Towns is reduced to the Service of Beasts and great Machines, which work under Man's Orders or Directions, and for him.

Two Sorts of Men are employed in these Works; *viz.* Engineers, who have the Direction of them; and Handicraftsmen, or Artists, who execute them. Engineers are not contented with composing the Proportions of the Lever, and Spaces over-run; they know that all Bodies are more or less rugged, and in the Frictions of the one against the other, are found Ups and Downs, Goings out and Comings in, or kinds of Jolts; that the Resistance of those Inequalities to the Slidings, is like the Resistance of the Teeth of a Saw rubbed against those of another; that those Shakings are like those of the Ascents and Descents of a Carriage on a bad Pavement; that if these Ascents and Descents, accumulated in the Extent of a League, are found by a like Calculation of the Value of 66 Fathoms of a perpendicular Height, which the Horse would have had to conquer; the Frictions therefore are a perpetual Source of the Diminutions of Profit in Mechanics. It becomes very well the great Masters, one M. *Delidor*, for Example, to foresee every thing, to estimate every thing, to assign, precisely, the Proportions, Gains, and Losses. His Hydraulic Architecture can even put the Reader in the way of Invention.

The Workmen, or Artists, have another Merit, *viz.* that of following a Model proposed, or imitating a known Machine, in taking for a fundamental Maxim of their Conduct, that of finishing always with Care and a curious Application, what they propose to imitate: The only Means to give the Pieces their just Quantity of Motion, and avoid the Mistakes which must result from the Roughness of the Contact.

Instead of a Dissertation on the Machines most in Use, and the different Tools of Artists, I content myself with sending you their Figures, with an Enumeration of their principle Pieces. It will be no longer necessary to shew you the Comparison of four Levers, more than thirty Feet each,

each, which form the four Wings of a Mill, with a Lever of about three Feet some few Inches, which are the Radius of the Mill-stone placed in Equilibrio on its Axis; nor to compare the Spaces over-run on either Side. It is the same Principle every where.

In the Execution of most of these Figures, I have been happily assisted by the Hand of M. *Leander*, a *Swedish* Artist, and excellent Drawer, sent by the Court of *Stockholm* to take the Plans of the Manufactures, and other fine Establishments in *France*, which was granted him without Jealousy or Restriction. He has communicated to me fifty Draughts after Nature, where you will be surprized at the Choice I have made of the most common Machines. They are very well contrived; and we seldom care to see any thing but their Outside, and even that afar off.

The preceding Machines, and a great Number of others, draw their principal Success from the Equilibrium found between a small Power and a greater, when the small is armed with a long Lever against a shorter, which serves as an Agent to the greater. These Powers and Levers are not always the same, at each Instant, in the same Machine. The Percussion of the Water on the Ladles, or of the Wind on the Vanes, can change. The Length and Direction of the Levers vary often in a single Revolution. When one of the Lifts of the Canting-wheel begins to meet with the End of the Stay of a Pestle, those two jutting Pieces form a Lever. In Proportion as it ascends and moves forwards under the Stay, the Line becomes straighter, and the Lever shorter. Therefore the Force of the great Lever of the Wheel is greater at that Instant: The more the Lift and Stay continue to ascend, the more they deviate from the right Line and advantageous Situation. The Mechanist knows the 70 Pounds which a Cube Foot of Water weighs. He knows whether he gives one or two Cube Feet of Water, or more, to his Wheel, and what is the Length of his Wheel. He estimates the Action thereof jointly with the Fall of Water which drives it. He knows also how much a Pestle weighs, how much the Four which the Canting-wheel keeps up: he compares the reciprocal Proportions of the Levers and Powers in all Situations and Cases. He knows them, and brings them to his End, either by precise Calculations, or repeated Experiments. The Enterprize

terprize of conquering great Resistances, is like a Conquest which degenerates into Temerity, when we attempt it without having foreseen the Obstacles, and calculated the Expence.

After the happy Application of the Lever to so many Machines, which increase almost without Limits, the Power of Man, and the Successes of his Works; here is another Means, equally simple and equally useful in the Mechanics. It is the inclined Plane.

The inclined Plane.

1. When it is wanted to make a heavy Body ascend, or to moderate its Descent; if it marches in a right Line, without holding to the Ground, its whole Weight must be supported: And then the Power must be equal or superior to the Resistance of the whole, to manage it.

2. When the Weight is on the Ground, the Line of its Fall finds an insuperable Obstacle, and cannot descend lower; it is supported, and, as it were, repulsed in a Line directly contrary to that of its Gravity. These two Lines destroy each other, and the Body remains at Rest. It can be taken from it and moved, either on an even Ground, or inclined Surface. If we want to move it forwards on an horizontal Plane, the Thing is easy in Proportion as this Body is terminated by a great Number of Faces very near approaching a round Figure: For leaning but on a small Surface, and as on a Point, its Weight can be conceived as a Line which falls directly from the Center of the Mass to the Point of Support. The Parts which are distanced from it on either Side are in a kind of Equilibrium, which can be disturbed by a very small Impulsion, and the Side which is not touched will give way, to seek a new Support. That Body will roll: Or if it presses the Earth with a too great Surface, and cannot be dragged along but with Frictions which multiply the Resistances, that Body is lifted up on a Chariot; the Wheels whereof, touching the Ground but by some Points, facilitate the Removal of the Side opposite to that of the Impulsion. Such is, therefore, the Benefit of small and great Wheels. They lend their orbicular Form to Bodies the most distant from that Shape. They diminish the Frictions in holding to the Ground but by a small Number of Points; and forming, on these Points, a kind of a perpetual Counterpoise,

Poise, they are always ready to obey the first Impulsion which shall determine them on one Side rather than the other.

3. Between the Motion of Bodies which ascend or descend perpendicularly, and the March of the same Bodies transported on an horizontal Line, there is a third Manner of moving, which is to move forwards on a Plane inclined to the Horizon; for Example, on the Declivity of a Hill, or on the Flight of a Terrass. In this Case, the heavy Body is in Part supported on a Line by the Ground, and in Part carried off on another Line by the Gravitation which carries it to the Center of the Earth.

Let us press a very smooth or even Floor with a Stick placed perpendicularly: That Stick remains at Rest. But if we incline it when we lay it on the Floor, it will slide, and the more it is inclined on the Floor, the less Resistance we shall find. The Line of Gravitation which must be imagined from the Center of the Masses to the Bottom, descends perpendicularly on the Horizon. But if it meets with an inclined Ground, it becomes oblique to that Ground; therefore it must either slide or roll upon it. A heavy Body which slides or rolls on a Declivity, is so much more supported upon it, as the Line of the Ground is inclined to the Horizon, and approaches the Perpendicular. An inclined Ground gives therefore Means to manage the most heavy Masses. Man discomposes dexterously the Weight thereof. He knows how to make Part of it bear on the Ground, reserving only to himself that Part which it is in his Power to manage. Geometricians do not fail following this Discomposition, and expressing it by Lines which leads them to a Rule, as follows:

Let a Power, which I call P, keep up the Body R of a spherical Figure on the Plane S H, according to the Direction C M P; there will be Equilibrium, if that Power be to the Weight as the Perpendicular F D is to the Perpendicular F A; *i. e.* there will be Equilibrium, if the Power and the Weight be reciprocally as the Perpendiculars F A, F D, carried from the Point of Contact F to the Directions C P, C F. *Plate* IV. *Fig.* 1.

I will have, if possible, the Weight R overbalance the Power P, and the Center C to descend in g, the Direction

M P

M P remaining always parallel to itself. From the Point g, let g N be carried parallel to the Base H O: The Center C, in its Fall, will have drawn near that Base of the Quantity C E. Thus the Weight R will have over-run towards the Center of the Earth, the Value of the Line C E according to its Direction, when the Center C shall be arrived in g. Likewise if we carry C g perpendicular to the Direction e P, the Power P will have over-run the Space G g, by acting against the Weight according to Directions always parallel to C P: For the Power P tends directly towards distancing the Weight R from the Line G C perpendicular to the Direction M P. But since the Power P is obliged to yield, it follows, according to the Hypothesis, that the Space it will over-run, contrary to its own Direction, will be measured, when the Center shall arrive in g, by the Part g G of its Direction M P, included between the Center and the Perpendicular C G, or, if you will, by its Equal C L. Therefore the Spaces over-run by the Power P and the Weight R, are equal to the Lines C L, C E.

The Direction C M P must be prolonged so far as to meet the inclined Plane S H at the Point B. The Triangle g C E is semblable to the Triangle E C N, because the Triangle g C N being rectangular, the Perpendicular C E divides it into two other semblable Triangles; having N common, and each a right Angle. As F D is parallel to E N, the Triangle C f D is semblable to the Triangle g C E. Therefore the homologous Sides, *i. e.* which are opposed, in it, to equal Angles, are proportional. Therefore g C is to C F, as C E is to F D. The Hypothenuse of g C E is to the Hypothenuse of C F D, as the small Side of g C E is to the small Side of C F D.

Likewise the two Triangles A C F, L g C, are semblable: For the Triangle L g C, is semblable to the Triangle C F B, since the Angles in L and in F are right Angles; and, besides, the alternate Angles g C L, C B F, are equal. The Triangles then, L g C, C F B, are semblable. But the Perpendicular f A divides the rectangular Triangle C F B into two other Triangles, alike between themselves, and semblable to the great one. Therefore the small Triangle A C F, being semblable to the Triangle C F B, is found semblable also to the Triangle L g C.

There-

Therefore the homologous Sides of the Triangles L g C, A C F, are proportional. Therefore g C is to C F, as C L is to F A: But we have just proved, that g C is to C F, as C E is to F D. Consequently C E is to F D, as C L is to F A: or F D is to F A, as C E is to C L. But we have supposed that the Power P is to the Weight R, as C E is to C L: Therefore the Power and Weight are reciprocally as the Spaces they over-run, one of them following, and the other against its own Direction. Therefore, according to what has been said of the Lever, there is Equilibrium.

If the Direction M P of the Power P be parallel to the inclined Plane S H, the Space which the Weight R did over-run in following the Direction of its Gravity, is also equal to C E, and that which the Power P did over-run against its own Direction, in moderating the Fall of R, is equal to g C: And we will shew also that these Spaces are between themselves as the Perpendiculars F D, F A, carried from the Point of Contact F to the Directions C E, and g C M P. Consequently the Power and Weight are reciprocally as the Spaces over-run. Therefore there is Equilibrium. But the Spaces C E, g C, constitute with e E a rectangular Triangle g C E, semblable to the Triangle H S O: Therefore, in the Case of an Action directed parallelwise to the Base of the Plane, the Power is to the Weight as the Altitude S O is to the Base H O; and there will be Equilibrium. It is what happens in the Action of the Wedge. Such are the Proofs which Geometry furnishes us with. These are of M. *Trabaud*, who has treated, in a very clear Manner, of the Equilibrium.

Plate IV. *Fig.* 2.

We may observe, besides, that in the first of these three Dispositions, the Direction of the Power approaching nearer the Perpendicular, than does the inclined Plane, it don't receive from that Plane so much Service, as if it was to imitate the Inclination thereof. We see in the third Disposition of G M P (*Fig.* 2. *Plate* IV.) that the Direction of the Power approaches nearer the Base than does the inclined Plane, and has against itself the Resistance of the Plane, and Gravity. The most favourable Disposition is the second, where the Direction of the Power is parallel to the Plane, and the Effort of that Power diminishes with

regard to the Weight, as the Length of the Plane increases with regard to the Altitude.

But without having Recourse to the Comparison of the Lines and Triangles to fix that of the Power and Weight, Experience has often sufficed to render sensible, and even to measure the Proportions of the Powers which counterbalance each other on an inclined Plane. Our Flights and Stair-cases are nothing else but inclined Planes; whose Inconveniences increase in Proportion as they approach a Perpendicular. If we want to raise a Cask of Wine on a Dray, the Dray is made with an inclined Plane. If we want to transport a heavy Burden from a lower Ground on a higher, it is by joining the two Grounds by Means of a Support which runs sloping; and the more the Declivity is protracted, the greater is the Help. Whence we conclude, by natural Geometry, that the more Ground the Power over-runs by making the Weight ascend a little, the more it acts against it; or, which is the same, that a small Power which traverses a great Space can be equivalent in Force to a greater which traverses but a small one. The Carrier who finds himself stopt by a moving Ground, where his Wheels are sunk as far as to the Axle-tree, does not deliberate whether he shall support the Weight of his Carriage, by drawing it out perpendicularly. His Jack has no Hold; and he finds neither in his Arms nor in his Levers, any Means sufficient for the Purpose. But without Masters and Calculations, he has recourse immediately to his Pick-ax and Spade: He removes the Ground from before the Jants of his Wheels, and opens two smooth Declivities. The further off he opens them, and approaching a Level by their Length, the easier the Wheels are disengaged or freed from the Obstacle. The last Example will make us understand quite how the Measure of this Help is fixed.

We want to carry Cannons of three thousand Pounds Weight, or more, into a Citadel built on a Plain at the Height of thirty Fathoms, and situated, on one Side, on steep Rocks, and on a Declivity on the other. This Ground may be very steep; for Example, of 40 or 45 Fathoms in Length, by 30 in Height; or there may be a Road which has several Windings, and makes up, by that Means, the Value of 100 or 150 Fathoms. Or it will be

of

of ſuch an Extent, as to render it naturally very acceſſible, for Example, of three hundred Fathoms always by thirty in Height; or of 500, or 4000. In all theſe Diſpoſitions, muſt be conquered, firſt, the horizontal Diſtance from the Place whence the Cannon is tranſported to the Foot of the Citadel; and ſecondly, the Height of thirty Fathoms to bring it to its Point, and place it in Batteries. Three Horſes can ſuffice to carry, ſlowly, a three thouſand Pound Weight in an horizontal Line: There needs more or leſs Help or Succours to conquer the 30 vertical Fathoms according to the diverſe Diſpoſitions of the inclined Ground. In the firſt, which is of thirty Fathoms Declivity by 30 of Height, it would be ſooner done to raiſe the Cannon with Pulleys and Engines, than to drag it over the ſteep Ground. In the ſecond, where the Road is lengthened into Ziczacs, we ſhall be obliged to add, to the uſual Number of Horſes, which would be ſufficient on the Plain, the Succours of three or four more. On a Declivity of two hundred Fathoms, or longer, we ſhall want ſucceſſively but two, or even one additional Horſe. Laſtly, on a Ground which will be of two, three, or four thouſand Fathoms, compared to thirty vertical ones where the Cannon is to be carried, each partial Elevation which the Horſes gain on the vertical Line from one Pace to the other, is ſo inſignificant, and coſts them ſo few Efforts, that that long Declivity does not differ ſenſibly from the horizontal Line; and in this laſt Diſpoſition, the ſame Number of Horſes which ſerve on the Plain, will ſerve on the inclined Plane. On this is founded this new Principle of Mechanics; *That the Reſiſtance diminiſhes with regard to the Power, as the Length of the inclined Plane increaſes with regard to the vertical Height*; or, which is agreeable to the Principle of the Lever, that the Powers which act on an inclined Plane, are reciprocally between themſelves, as the Spaces they over-run; one of them according to its own Direction, and the other againſt its own Direction.

The ſame Advantage is found, with the ſame Proportion, in the Uſe of the Wedge uſed to cleave Wood, or any other Matter. The Wedge is nothing elſe but an inclined Plane. The Percuſſion which drives it, is but a ſtrong Preſſion. The Diſtention of the Borders of the Aperture anſwers to the vertical Height, and the Intro-

duction of the Wedge into the Wood answers to the Length of the Plane. The greater the Insinuation and the smaller the Aperture are, the less Resistance is felt by the Arm.

The same Principle is verified in the Use of Knives, Pins, Hatches, and all that enters with violence into what we want to separate or cleave.

The Screw. Plate IV. Fig. 3.

It is found in the Screw, which is also an inclined Plane, and leaning round a Cylinder. There are two Sorts of Screws: The interior Screw, which has its Spirals or Furrows in Relievo: The exterior Screw, which has its Spirals concave to receive the interior. The first is properly called Screw, and the second, Nut; to it is added the Use of the Lever. The Cylinder is driven, with its Spirals, in the Manner of the Axle-tree of a Hand-mill; and in Proportion as the Spirals of the Screw enter the Nut obliquely, the Cylinder conquers, by Degrees, some Points in the vertical Height, raises what is a-top, and presses perpendicularly what is underneath. The more these Spirals are inclined, and near one another, there is less Height to be conquered at each Instant. It is a Conveniency like that found at one's Arrival on a Terrass extremely exalted, in turning on the Windings of so easy an Ascent, that it differs very little from an horizontal Line. In the Flight and Screw the Fatigue of raising a Weight, or one's own Body, to a certain Height, increases in Proportion as we want to diminish the Length; what we want to gain on Time is lost on the Forces; and Man has much more Interest to manage his Forces than his Time.

Though the Frictions are great in the Use of the Screw and Nut, in Proportion as the Surfaces which touch one another are long, that Disadvantage, which is as an Increase of Length or Resistance, is repaired or moderated, first by the perfect Conformity of the Height or Diameter of the interior and exterior Spirals in their whole Extent; secondly, by the Length given to the Lever which makes the Cylinder ascend or descend: The Valuation of the Service of this Machine results from the Comparison of the Spaces over-run by the Cylinder and Lever. The Power is in an inverse Ratio of those Spaces, the Frictions set apart. The End of the Lever, and the Power applied to it, trace a circular Line, which can be unfolded and reduced

duced to a right one; the Lever, which is the Radius of that Circle, making a fixt Part thereof, and a little more. If the Compaſs made by the Screw and Reſiſtance in a perpendicular Line is the hundredth Part of the Compaſs made by the Lever, the Power of a Pound, applied to the Lever, will lift up a Reſiſtance of the Value of a hundred Pounds applied to the Cylinder, or make it deſcend. Such is the Meaſure of the Succours found, though with unequal Makes, in the Printing-Preſs; in the Calender's Preſs; in the little Preſs-houſes, where, with the Aſſiſtance of a long Lever, the Head of a ſtrong Screw is lowered on a Heap of Grapes or Olives, which are to be ſqueezed.

I have ſaid, that this Calculation would be croſſed by ſome Miſ-reckoning in the Execution; not becauſe we do not know the preciſe Proportion of the circular with the right Line; our Method of reducing the Circumference of the Circle to three Diameters and ſome Points, being very near ſufficient for the Uſes of Life; but becauſe there is in moſt Machines, and eſpecially in this, unequal Frictions, which deprive us of Part of our Hopes; but Man is pretty well off, if endeavouring to conquer with one Pound of Force a Reſiſtance of an hundred Pounds, he conquers but one of twenty-four. His Labour is yet much more to be valued if he has foreſeen the Waſte.

Beſides the Friction of the Nut, the Screw has this Inconvenience, that its Uſe is confined to the Aſcent and Deſcent of the Cylinder, and that Cylinder having but a very little Height, cannot lift up Burdens ſo high, nor work at a great Diſtance. There has been found a Screw which has none of theſe Inconveniences, and its Benefit has been increaſed in ſuch a Manner, that it appears like a kind of Prodigy, when the Wheel-work is joined with it. This Machine is called Endleſs Screw.

The Endleſs Screw, *Plate* IV. *Fig.* 4.

In the Screw with a Nut, one entire Revolution of the Handle moves the Cylinder forwards the Interval of one Spiral to another Spiral; and the nearer the Spirals are one another, the eaſier it is managed, becauſe of the Superiority of the Space traverſed by the Lever over the Space traverſed by the Cylinder. In an endleſs Screw the Cylinder turns without going forwards or backwards; but a Wheel, whoſe Plane is parallel to the Cylinder, or whoſe

Axis is perpendicular to the Axis of the Screw, opposes its Teeth to the Spirals of the Screw. These Spirals turning with the Cylinder drive the Teeth inserted in them, and slip from them, to meet them again by a perpetual Rotation. The first Advantage of this Machine consists in the Comparison of the Space over-run by the Handle, more or less long, and the Space which parts one Spiral from the other. The second Advantage results from the Comparison of the Radius of the Wheel with the Radius of the Roller B, where the Weight A is fastened. Let us suppose an Interval between two Spirals to be as 1, and the Circumference of one Turn of the Handle as 100. Let us suppose the Radius of the Roller to be 1, and the Radius of the Wheel 5, *i. e.* five times as long as that of the Roller: The Radius of the Roller must be multiplied by the Interval which is between two Spirals; and the Radius of the Wheel multiplied by the Circumference described by the Handle in one Revolution: The Proportion of the Power and Weight will be equal to the Proportion found between the two Products. For if the Power, for Example, your Hand, was immediately applied to the Point C of the Wheel (*Plate* IV. *Fig.* 4.) your Action would be to the Weight A as the Radius of the Roller is to the Radius of the Wheel. If the Radius of the Roller is the fifth Part of the Radius of the Wheel, it suffices that the Effort of your Hand, applied to the Circumference of the Wheel on the Teeth C, be the fifth Part of the Effort of the Weight A. But if instead of conquering that Resistance by the Application of your Hand in C, you drive in C the Spirals of an Endless Screw, you acquire a Force much superior to the preceding one. Your Strength is now to the Resistance, which it feels in C, as the Intervals which separate two Paces of the Spiral Thread.* is to the Circum-

* It is indifferent whether the Power draws against an inclined Plane, or the inclined Plane drives the Power. All partial Actions of the Points of a Spiral against the Teeth opposed to it, are perpendicular to the Height of the inclined Plane, and parallel to the Base. But we have seen above, that when the Direction of the Power, as G M P, was parallel to the Base, the Power was to the Weight as the Height to the Base. Here, it is the Revolution of the Cylinder which is the Base; and the Interval of one Spiral to the other which expresses the Height of the Plane.

ference described by your Hand applied to the End of the Handle. If the Interval between two Spirals is but the hundredth Part of the Circumference described, it will be enough if your Hand makes an Effort of the hundredth Part of the Resistance found in C. But the Resistance found in C is, as we have seen already, but the fifth Part of the Ponderosity of the Weight A. Therefore it suffices that the Effort of your Hand be the hundredth Part of the fifth of the Weight A; or that that Effort be to the Weight A, as 1 *Pound* is to 500. But these Numbers are, one the Product of the Radius 1, which is the Radius of the Roller; and the other the Product of the Radius 5, which is the Radius of the Wheel, multiplied by the Circumference 100, the Compass of the Handle compared to the Interval of two Spirals. One by one gives one, and five by a hundred gives five hundred. Therefore the Power is to the Weight as the Product of the Radius of the Roller, and of an Interval between two Spirals is to the Product of the Radius of the Wheel and of the Circumference described by the Handle of the Screw. This second Advantage of the Endless Screw can be increased by the Multiplication of the Wheels, by lengthening the Handle, and by all Sorts of favourable Proportions.

The third Advantage of this Machine is, that it can act at very great Distances. The Wheels combined with the Endless Screw have their Axis and Roller, round which a Rope or Cable can spin, which will draw an enormous Weight, and from as great a Distance as you will desire.

The Endless Screw, we see so proper to manage the great Weights which are to be transported, is no less useful to manage those whose Fall we want to moderate. We find the Idea thereof in the common Jack; whose chief Use, after that of exposing, with Uniformity, to the Fire all the Sides of a Piece of Meat, is to lengthen the Service of the Weight by the Delay of its Fall. This Weight follows the Slowness of the first Wheel, which accelerates the Motion of the second, because this makes as many Revolutions as a Pinion does in exhausting all the Teeth of the first. Thus the Celerity increases from Wheel to Wheel by the Insertion of as many Pinions. All the Impetuosity of this Acceleration lies on an Endless Screw, which moderates it, and is itself slackened in its Rapidity by two

or four Iron Arms, which load the Cylinder of the Screw, and resist the Motion of the Cylinder in Proportion of their Length, and to the Mass of Lead their Ends are loaded with.

The Screw or inclined Plane, which incompass a Cylinder, has taken other Forms of great Utility in the common Uses of Life. If the End of the Cylinder be sharpened, that Screw becomes a Gimblet or a Turrel. But if the same Instrument be made ever so little broader, it forms a Wedge of a very bad Use, which splits Boards, and disorders every thing. The Spirals of this Instrument have also been made sharp or cutting, and its Cylinder hollow a-top, in the Shape of a Spoon, so that the Parts of the Wood, whose Place is supplied by the Body of the Instrument, are no longer forced to contract themselves to give way to the Body of the Screw. All these Parts slip thro' the Aperture of the Spoon, and no longer increase the Resistance. Such is the Disposition of the Wimbles, Augers, *&c.* We always find in them the inverse Proportion of the Powers to the Spaces over-run: So that the Strength of the Hands which pierce a very hard Wood, wants only to be to the Resistance, as the Progress of the Screw into the Wood is to the Length of the Arms of the Auger.

This Proportion of the Forces to the Spaces over-run is found also in the Counterpoise of Liquors. Mess. *Pascal*, *Mariotte*, and *Belidor*, are those among us who have explained with greatest Accuracy and Success, the Principles of the Static of Liquids, and Waste of Water in all the Uses which can be made of it: But this Part of the Mathematics, in which so great Progresses have been made, is yet subject, in several Articles, to various Disputes. We discover daily, in it, new Reasons to act with Circumspection; and the best versed in those Matters have the Prudence not to attempt the greatest Enterprises till after they have, by repeated Experiments, made themselves sure of Success.

To the preceding Examples, whereby you see sufficiently, what Sort of Learning puts Man in Possession of his Demesne; I'll add but one more, to acquaint myself of my Promise: Which is that of the Penetration wherewith Opticians have observed the Processes of Light in its different Falls, and, in Consequence thereof,

of, regulated the Instruments, which multiply its different Uses.

Of Optics.

DIALOGUE XV.

LET us begin by the Method of Opticians; we will come afterwards to the Benefits reaped from it.

Light falling on Surfaces which it cannot penetrate, and passing through Bodies which transmit it from one Surface to another, is susceptible of various Changes. Opake Bodies beat it back or reflect it, at least in Part; and diaphanous Bodies do not suffer it to pass otherwise than in bending the Line it followed, or diverting it out of its rectilineal Course. The Inflections it receives, either in breaking in transparent Bodies, or reflecting on the opake, are so many Angles. The Accuracy of the Remarks of Optics on the Effects of these Changes, depend entirely on the Knowledge of the Angles formed by the Rays in their different Inflections, or Bendings. *Snellius* and *Descartes* have, better than any body else, determined the Value of these Angles, by inscribing them in their Circles, the better to judge of an unknown Angle by the Assistance of its Arch and Sine, or other known Lines; but more particularly to establish in all Cases a constant and assignable Difference between the Angle of Incidence and that of Reflection. By placing an Angle in a Circle, it may be known; and to compare it with another, we must employ the Knowledge of the Radius, and that of the Sine, Tangent, or Secant. Or we must be contented with considering the Lines formed by the Rays and Surfaces, to take among them semblable Triangles, whose corresponding Sides may be put in a Proportion: So that the Knowledge of several Sides, or several Angles, helps towards the Discovery of the Side or Angle which remained hid. And

whether we approve of semblable Triangles, or employ the Help of Sines, or other subsidiary Lines, it is most commonly the Practice to proceed by the Rule of Three, or of Proportion; the Use thereof is of so great an Extent, not only in Optics, but also in all the Applications which can be made of Measures and moving Forces, that we cannot help considering Proportion as one of the most perfect Instruments of the Knowledge of Man.

Proportion is a Combination of several Ratio's compared together. The Proportion of a Line with another Line, or a Number with another Number, is what we call Ratio; the Ratio of 6 to 12, is to be half of 12: The Ratio of a Line of 6 Inches to a Line of 18, is to be found 3 Times in it. In the Ratio of 6 to 18, the first Term 6 is the Antecedent of the Ratio; and the second Term 18, is the Consequent.

We not only compare an Antecedent with a Consequent, but the Ratio or Proportion of the one to the other is also usefully compared with the Proportion of two other Terms considered at the Rate, one, of a second Antecedent, the other, of a second Consequent. For Example, 2 is half 4, as 3 is half 6: 1 is to 3, as 6 is to 18. Here the first Antecedent is 1, its Consequent is 3; the second Antecedent is 6, its Consequent is 18.

The Comparison made of the Proportion, which is between two Terms, with the Ratio found the same between two others, is therefore what we call Proportion: And this Comparison is most commonly composed of four different Terms, which are the two Extremes, and the two Mediums. In this Proportion 1 is to 3, as 6 is to 18; 1 and 18 are the Extremes; and 3 and 6 the Mediums.

Often the Proportion subsists with three Terms only; because the Consequent of the first Ratio can be repeated, and become the Antecedent of the second; it is called then a Mean proportional: As 2 is to 4, what 4 is to 8; the Term 4 is the Mean proportional, and is repeated, because 2 is half 4, as 4 is half 8: 1 is to 11, what 11 is to 121; because as Unity is repeated eleven Times in Eleven, likewise Eleven is repeated eleven Times in 121. Eleven, therefore, is here the Mean proportional, since it enters by Turns the two Proportions compared together.

There

There are several Manners of ordering Proportions, which all have their Application and Utility. Let us consider only the most important Property of Proportion, and the great Use made of it. The particular Property of Proportion consists in, that the Product of the Extremes multiplied by one another, is the same as the Product of the Means multiplied by one another. In this Proportion, 2 is to 4, as 3 is to 6; the Extremes 2 and 6, being multiplied by one another, the Product is 12; and the Means 4 and 3, being multiplied by one another, give also 12 for a Product: Because it is the same to multiply 2 by the Double of 3, as to multiply 3 by the Double of 2. Likewise if we say, 2 is to 4, as 4 to 8, we find that 2, the first Term, multiplied by 8, which is the other Extreme, produces the same Sum as 4 by 4, which is the Mean proportional; it is 16 on either Side; because it is the same to double the Double of four, as to quadruplicate the Double of two.

Property of the Proportion.

This Equality of the Product of the Extremes with the Product of the Means being infallible, the great Advantage which has resulted from this Observation, is to assemble the three first Terms of a Proportion, and oblige the fourth, though unknown, to discover itself. If three of my Servants have eat this Year 80 Bushels of Corn, how many Bushels will twelve of them eat the next Year? 3 is to 80 as 12 is to a fourth Term, which I search, and I must find it. For having multiplied both Means one by the other, *viz.* 12 by 80, I find 960. But if the Product of the Mediums be the same, what must be that of 3 multiplied by the Number which is to come? As 80 is found 12 Times, or twelve 80 Times in 960; therefore the Number of Times I'll find 3 in this Product must be the fourth Term I search: Which will be infallible, if that fourth Term multiplied by 3, which is the first Extreme, give the same Product as the Means give. I search, therefore, how many Times 3 in 960; I find it 320 Times. But 320, multiplied by 3, give the same Product 960: Therefore 320 is the fourth Term unknown brought to Light.

The Use of this Property.

This Operation, which is the same in the Comparison of Numbers, Magnitudes, and Forces, is called, you know,

Golden Rule, by Reason of the Value of its Productions. When there are several Proportions to be made, the Expression or Sign thereof, can be abridged by writing them in this Manner, 1, 3 : : 6, 18. 3, 80 : : 12, 320. And when a Mean proportional is employed in it, it must be wrote thus : .:: 25, 50, 100, instead of 25, 50 : : 50, 100.

Let us see how Opticians work the Proportion to support their Assertions. We will take for Examples, two Proportions only. One whereby the Opticians teach to determine all Sorts of Altitudes, with the Assistance of a Mirrour; the other, whereby they explain why Bodies, moved with the greatest Rapidity, appear at Rest.

1. By supposing the Equality of the Angle of Reflexion with that of Incidence *, they establish a very simple and intelligible Rule to judge at once of the Altitude or Height of a Steeple, or Top of a Tree, by the Inspection of a Mirrour. Take, say they, a Pocket Looking-glass or Mirrour, and put it on the Ground at the Place where you begin to see the Height of the Tower or Cross, whose Elevation you search. When by moving the Mirrour forwards or backwards, you arrive at the Point, where from your own Height you perceive the Weather-Cock, leave the Mirrour horizontally on the Ground, and reckon the Distance between your Feet and the Mirrour, then that between the Mirrour and the Foot of the Tower. Conceive or trace three perpendicular Lines, and separated by as many small proportional Parts, as you have found Feet in these two Distances. 1. A Line which we will call h, and is the Height of the Observer; 2, the Perpendicular p to the Point of Incidence; 3. the indefinite Height of the Tower H. They are all three parallel. From the Height of the Observer h, carry a Line to the Incidence p: It is the reflected Ray. Carry another Line under the same Angle from p to such a Point of the indefinite H, as it will be able to reach; this will be the incident Ray. Now this Incident Ray H p, makes with the Line H and the Perpendicular p, two equal Angles, since they are alternate between Parallels. It makes, also,

To measure a Height by the simple Succours of a Mirrour. Plate XV. Fig. 1.

* See Spect. de la Nat. Vol. iv. Dialog. viii.

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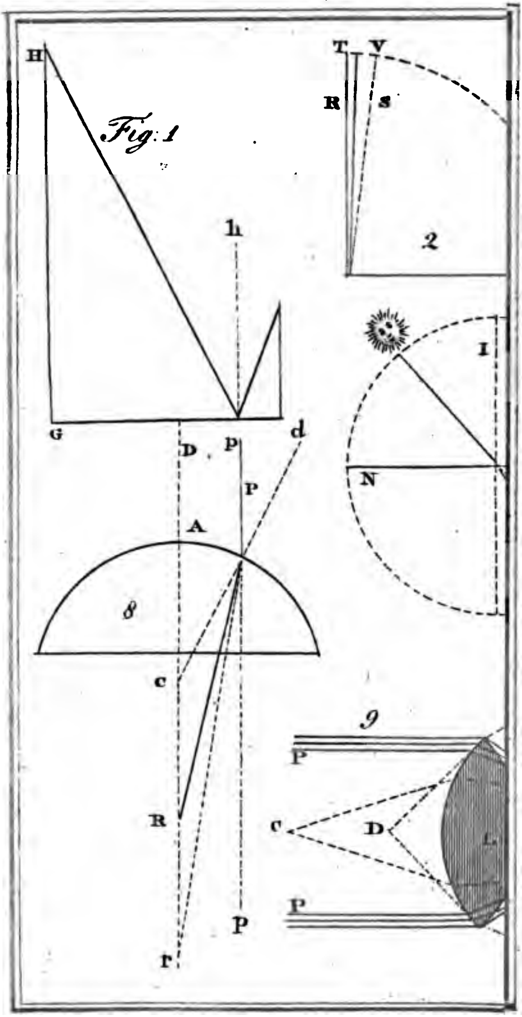
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as many in its Reflexion between the Perpendicular p and the Height of the Observer h. The Angle G is a right Angle in the great Triangle; and the Angle d is a right Angle in the small Triangle. The Angle G and the Angle d being each of 90 Degrees, besides the Angles H and h being equal on either Side, it is necessary that each Triangle should end its Equality with two right Angles, by the Equality of the two remaining Angles D and p: Therefore the great and small Triangles are semblable, therefore their Sides can be compared together, and the corresponding Sides will be found proportional. From the Eye of the Observer h to the Horizon, let us reckon five Feet. From the Line of the Observer to the Incidence p, let us reckon the small Distance of two Feet. Let us suppose, though the Figure be too small to allow here a just Measure, that from the Incidence where the Weather-cock is seen in the Point p, we have found 70 Feet to the Tower: By putting these three first Terms in a Proportion, we must find the fourth, which will express the Height of the Weather-cock.

Therefore we will say: As two Feet small Distance are to five Feet, the Height of the Eye, thus 70 Feet great Distance are to a fourth unknown Measure H, the Height of the Weather-cock. Let us multiply the Means 5 and 70 one by the other; the Product is 350. In this Product how many Times the first Term 2? 175 Times. The first Term 2 multiplied by 175, gives the same Product as thetw o Means, *viz.* 350. We have therefore the fourth Term of the Proportion; and the Weather-cock of the Pyramid is infallibly at an hundred and sixty-five Feet from the Ground. Thus, without any other Preparation but that of a common Looking-glass, and a Figure traced in the Dust, we can, almost in an Instant, determine all Heights whose Foot is accessible.

Why, and when Bodies, who move with Celerity appear at Rest. *Fig.* 2.

2. Let us add another Example of the Certainty which accompanies the Assertions of Optics. A Body, say the Opticians, will appear at Rest from a Second to a Second, with whatever Celerity it turns round us, if the Space it runs over in the Interval of one Second, be to the Distance it is found at, with regard to us, but as an imperceptible Tangent with Comparison to the total Sine.

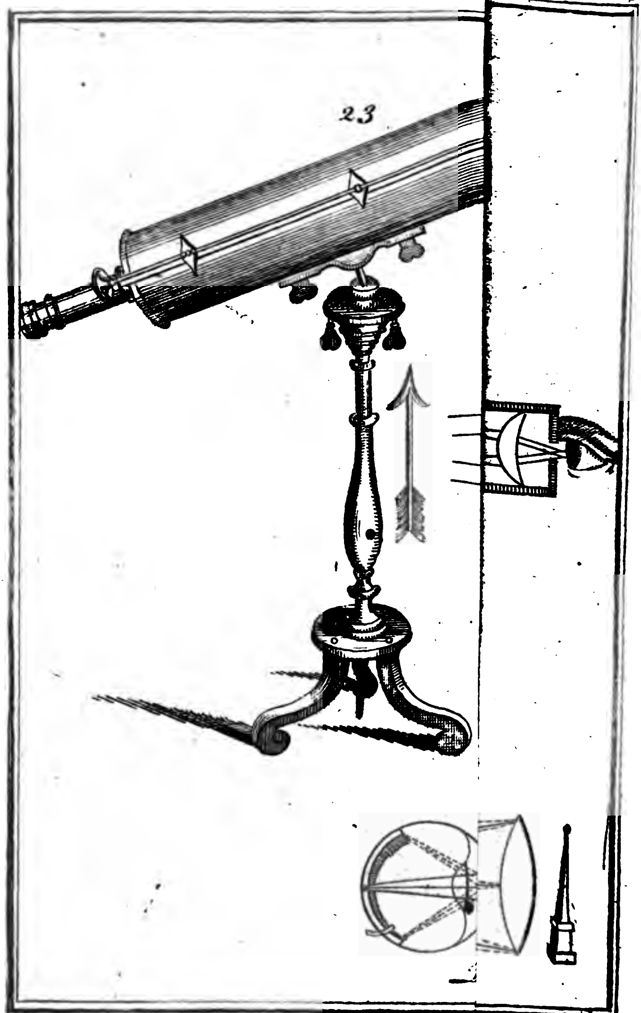
Let

Let the Radius, which is the same Thing as the total Sine, R; the Tangent, T; the Secant, which terminates it, S. The Space run over by a Body in Motion, is to the Distance from this Body to the Eye, as the Tangent is to the Radius or total Sine. Now the Radius being supposed of ten Millions of equal Parts, and the Tangent run over in the Interval of one Second being supposed of seven hundred twenty-seven Parts only, this Tangent is an insensible Space: The Secant in this Case is not yet separated for the Eye from the Radius: Therefore the Body which has run over, though with a great Celerity, all that Tangent, does not appear removed in the Interval of two Seconds, and seems always actually at Rest. The Removal of the Body does not become sensible, but by the opening of the Angle beyond that Measure we have just marked. For Example, the Transport or Removal of the Body in Motion will be perceived, when the Secant which carries it will be removed into V.

Astronomy proves the Truth of this Proportion *, and fixes the Opening to be given to the Angle to render it sensible. A heavenly Body in running over, in 24 Hours, the 360 Degrees of its diurnal Revolution, runs over 15 Seconds of a Degree in the Interval of a Second of Time. But that Space, though very great in itself, becomes imperceptible and as null, when compared with the Distance of the heavenly Body from our Eyes: It is as a Tangent of 727 Parts compared to a Radius or total Sine of ten Millions. Such is, by Calculation, the Proportion found between the Space run over from Second to Second by a heavenly Body, and the Distance of that heavenly Body: But, in Fact, that Space is insensible; and as the heavenly Body, in the Interval of two Seconds, over-runs no more than fifteen Seconds of a Degree, it always appears actually at Rest. Therefore it is the same with any Body in Motion, and perceived in the same Proportion. If the Space run over be to the Distance of the Eye but as 727 to ten Millions, it is the same Proportion as that of 1 to 1375: It is, as it were, a Nothing before a great Reality. A Motion seen under such Circumstances is therefore imperceptible.

* Father *Regnault*, Mathem. Conversat.

III. Pa. 279.



In this Manner Opticians have taken the Pains to justify all they have proposed. These Demonstrations are found in the Works of *Dechalles*, *Molineux*, *Musschenbrock*, Father *Regnault*, &c. But as in using the Proportions found between the Sines, Secants, and Tangents, these learned Mathematicians have supposed the Tables thereof ready made, without making them themselves; we can, without any Risk, leave them all the Calculations, and be contented with their best Lessons. They are agreeable Truths, and useful Instruments.

Light is the Object of Optics. We feel confusedly the Presence of Light, when some of its Rays, thrown at Random and without Order, enter our Eyes. We see a distinct Form when the Particles of Light, which enter our Eyes, are disposed in them from their Extremities, in the same Order with the Points of the luminous Body whence they flow, or the Points of the opake Body which has reflected them. We are going to see, in a Sequel of Propositions, how this is executed.

The Progress of Light.

1. Luminous Bodies, like sonorous ones, carry their Action all ways in the Sphere they are environed with, and the Surfaces, which Light meet with, reflect it, like Sound.

2. Light, like Sound, whatever Part it throws itself into, carries its Action on right Lines.

3. It is because the Lines of Sound and Light are right, and do not decline sidewise, that you are sure, by opposing to them such or such Surface, to inflect them, and make them take a new Road, but always a direct one, and to bring the Echo or Light to such or such a Point.

4. This is the first Foundation of Optics and Acoustics.

5. If the Horn which a Hunter sounds on this Side a Mountain is heard in a Valley beyond it; if in a great Wind you hear the Sound of a Bell, which you scarcely could hear before, it is because the Lines of the Sound of that Horn have been inflected at the meeting of a Wood, a Wall, a Rock, a thicker Air, one or two Leaves of a Tree, opposed obliquely to it; and one of these Lines arrives, from Inflection to Inflection, as far as into the Ears, whither its former Road did not lead it. The Air heaped up by the Wind becomes a Surface capable to throw obliquely, and in a greater Quantity, Lines of Sound into

Places

Places where they were not to be felt at first, because they had arrived in them too much diverged or weakened, or had not arrived at all. Likewise, if a Trace of Light, which cuts the Air between several Clouds, or traverses a dark Room, is seen sidewise, it is because those Spaces are full of Vapours, or of Pulvisculæ, massive enough to reflect laterally some Particles of these luminous Traces. They were not for you, and by that slight Reflexion you are informed of their Passage.

6. All these Lines of Light are confined within their Principles, and their Action is strong in Proportion to their Density. The greater the Sphere is they traverse afterwards, the more Room they gain, and their Action is weakened in Proportion to their Divergency.

7. The Rule of the Diminution of Light is in an inverse Ratio of the Square of the Distance. If you take a Globe and cut it in two Halves, you have in each Half the Surface or Plane of the greatest Circle. In this Surface take a Portion included between two Radii and an Arch, and traverse this Sector by a Radius divided into three equal Parts, to trace upon it as many Arches: This Sector, and consequently the whole Surface or Plan of the great Circle, will increase like the Square of the Radius. In a the Square of the Radius of one Foot, multiplied by 1, is 1. In b the Square of 2, multiplied by 2, is 4. In c the Square of 3, by 3, is 9. Farther off, the Radius of 4 Feet would give 16; of 5, would give 25, and so in the Sequel. The Ratio of the Decrease of Light is inverse of the Square of Distance: And if after having measured the Distance of the Hole of a dark Room, as far as to the Wall, you present at the Aperture a lighted Candle in a small Box, you will perceive that the Light received at one Foot from the Hole on a Sheet of Paper is very strong; that at two Feet from the Hole it diminishes, not by Half, but by a Quadruple, 2 having 4 for a Square; that thus its Diminutions are like the Squares of Increases of the Distance, so that where the Square of the Radius is 4, it is four Times less than it was at first; where the Square of the Radius is 9, it is, then, but a ninth Part of what it was at first; and at four, five, or six Feet, it is but a sixteenth, twenty-fifth, or thirty-sixth Part of what it was in coming out of the luminous Body.

8. When,

8. When, on the contrary, the Rays of Light, instead of diverging, converge, and incline towards the same Point in coming out as from the Base of a Cone to reach the Top, they grow stronger in Proportion as they approach the common Point where they are to be re-united, and the Increase of their Strength is still in our inverse Ratio of the Square of Distance; *i. e.* that Light goes then increasing, as the Square of Distance goes diminishing; so that the converging Light is 4, 9, 16, 25 Times stronger, where the Distance with regard to the same Point is found 4, 9, 16, 25 Times smaller than before.

9. Of several Rays falling from the same luminous Body, the most direct, according to the two preceding Remarks, is the most active: For it is denser since it is shorter. On the contrary, the obliquous protracting themselves more and more, are also more and more diverged and extenuated. Thus *Europe*, being considered as a long Surface, the Light of the Sun is shorter and more active on *Spain* and *Italy*, than on *France*; more on *France* than on *England* and *Holland*; more on this, than on *Sweden* and *Lapony*.

10. It is but a simple Divergency which weakens Light in the lengthening of the Obliquity; the Intervention of reflecting Bodies puts it more and more out of its Road. A Vapour blunts its Vivacity: It shakes, or seems agitated, like the Corpuscles which traverse it; and a Fog can thicken so far as to impede entirely its natural Fall. Care has been taken to study the March of Light, to direct it to our Advantage.

11. We call Radiant Point, any Point whence diverging Rays proceed. The Radiant Point.

12. We call Focus the Point of Concourse where the convergent Rays concur or meet. The Focus.

13. In a dark Room, and quite shut to Light, you can contrive in the Window a narrow Aperture, on a Plan parallel to that of the Sun: There will be found two Cones of Light opposite to the Vertex; one composed of Rays of Light proceeding from the Borders of the Sun, as far as to the Aperture; the other composed of the same Rays, which from the Point of Concourse, where they intersect each other, enter the Room in diverging by Degrees, and fol- The Image of the Sun in a dark Room.

low

low in it a Road contrary to the preceding one, after they have crossed each other. Cut this last Cone, by opposing a Pasteboard to it. If you oppose it parallel to the Plan of the Sun, you'll perceive on it the Image of the Sun, or the Base of the Cone perfectly circular. If the Paste-board cuts cross-wise, and without any regard to the Aspect of the Sun, this small Cone of Light, you'll see on the Paste-board the same Image, but irregular and lengthened: These are two Conic Sections. Let us understand ourselves. This small Pencil of Rays, which from its Point, placed at the Aperture of the Window, grows always wider and wider, is like a Sugar-loaf. Cut that Loaf so as all the Points of your Slice be equally distant from the Point or Top, it is a perfect Round. Take off a Quarter of the Loaf by cutting it sloping, it is an Oval.

14. That Image of the Sun appears inverted, because the Ray which proceeds from the upper Part of the Sun, descends into the Room on the Paper or Paste-board; and that Ray which proceeds from the lower Part of the Sun, ascends. That which comes from the Right to the Aperture of the Window, crosses that which comes from the Left, and pursuing their March into the Room, they are all found on the Image, in a Situation contrary to the preceding one.

15. It is for the same Reason, that if you leave but a small Aperture at the Window, you'll see the Objects of the Street painted on the opposite Wall; but the Picture is inverted, because the Ray that comes from the Threshold of the House, which is over-against your Windows, reaches the Top of the Image; the Ray which comes from the Top of the House reaches the lower Part thereof; that which comes from the Right to the Hole, passes on the Left of the Figure; and thus of the others. This Image is weak, because a Multitude of other Rays reflected by the neighbouring Objects, and forming other weaker Images on the Side of this, traverse it, and render it cloudy. We will see how it can be rendered more perfect, by dissipating those superfluous or foreign Rays, with the Assistance of a lenticular Glass, which disperses the superfluous, and approximates the good Rays.

16. In the Image of the Sun, taken with Care, one can observe the Spots of the Sun, see their Progresses, and

Removals at different Days, reckon how much Time elapses between the Moment wheu a Spot disappears, in passing under an Edge of the Sun, and that when it appears again on the opposite Edge. Thus we can know how many Days and Hours the Sun takes in its Revolution round itself. We can compare the Cone which extends from the Image to the Aperture, with the Cone which extends from the Aperture to the Disk of the Sun. We now put in a Proportion the Semi-diameter of the Image, its Distance from the Window, the Distance of the Window from the Sun: And by these three first Terms, which we pretend to know, arrive to a fourth, which is the Semi-diameter of the Sun. The Semi-diameter known, gives the Surface of the great Circle, and the Circumference. This will lead you as far as the Solidity. You will be able to know, within a small Matter, how many Cube Feet of Matter the Sun contains. This Image can also serve to something much more useful. It is divided into small Parts very well numbered, and on these Lines are measured, with great Accuracy, the Entrance of the Shadow of the Earth on the Disk of the Sun, in an Eclipse; the Progress of the Shadow, the Duration of its Passage, and the very Moment the Sun appears entirely freed from it. The Difference of the Hours when the same Event was observed at different Places, shews greatly by how much the Place of one Observer is more East than that of another, and serves to perfect Geography.

The Reflexion.

17. When a Ray of Light falls from a Medium on another Medium, for Example, from the Air on a Mass of Crystal, or the Surface of Water; there are Cases where that Light is reflected whole; and others, where it is reflected in Part, and in Part received in the new Medium.

18. What falls perpendicularly on a Surface and reflects upon it, raises along the same Perpendicular which has directed its Fall.

19. The Part of the luminous Beam which reflects on a Surface as E, after an oblique Fall, raises in the same Obliquity. *Fig.* 4.

The Angle of Incidence.

20. The Angle, made by an oblique Ray of Light with the Perpendicular, is the Angle of Incidence I.

21. The

The Angle of Reflexion.

21. The Angle, made by the Line of Repulsion with the same Perpendicular, is the Angle of Reflexion R.

22. The Angle of Reflexion is always equal to the Angle of Incidence.

23. The Ray, or Part of the luminous Beam which penetrates perpendicularly out of a Medium into another, traverses the Second at the Perpendicular, and without Inflection, either by passing out of a rarer Medium into a denser; as out of Air into Crystal, or out of a denser Medium into a rarer, as out of Water into Air, and out of a thicker Air into a rarer.

The Refraction, and Dioptric.

24. If the Ray arrives obliquely on the Surface of the new Medium N M which it enters, it declines from its first Directions, and is inflected either by approaching the Perpendicular, or deflecting from it. It makes with the Line, perpendicular to the Surface of the Medium where it is received, an Angle, smaller or greater than that of Incidence, according to the Nature of the Mediums. It is called Angle of Refraction. R, *Fig.* 5. is an Angle of Refraction, smaller than that of Incidence I.

The Angle of Refraction.

25. The Line of Incidence I, prolonged in the new Medium, makes with the Line of Refraction R, a small Angle D, called Differential Angle; because it shews in what the Angle of Refraction R differs from the Angle of Incidence I.

Differential Angle.

Value of the Angles of Refraction according to the Mediums.

26. When the Ray I passes out of a rarified Medium, such as Air, in the new denser Medium N M, such as Water or Glass, it makes an Inflexion when it approaches the Perpendicular, and an Angle of Refraction R smaller than that of its Incidence I.

27. When, on the contrary, the Ray, for Example R, being reflected from an Object which is in Water in R, passes into a new Medium less dense than the Air, it breaks according to the Line I in deflecting from the Perpendicular. Thus it makes in the Air the Angle of Refraction I greater than R, of the Quantity of the small Angle D.

28. By the exact Comparison which the most celebrated Opticians have taken Care to make of the Sines of all these Angles,

Angles, we have been rendered capable to establish a constant Proportion between the Angle of Incidence and that of Refraction, out of one Medium into another. Thus the Ray which passes out of Air into Glass, breaks in it under an Angle, which is, with regard to that of Incidence, as 2 to 3. And then the Differential Angle is Half, or almost Half the Angle of Refraction, and a Third of the Angle of Incidence. At the Passage out of Air into Water, the Ray is less inflected, the Differential Angle smaller, and the Angle of Refraction a little greater than in Glass. This is to the Differential Angle as 3 to 1: The Angle of Incidence is to the Angle of Refraction in Water as 4 to 3: Therefore it is to the Differential Angle as 4 to 1. Since the Angle of Incidence, which is equivalent to the Angle of Refraction and to the Differential Angle together, contains, necessarily, 3 and 1, by Comparison with the two others. If, on the contrary, the Ray passes out of Glass or Water into Air, it makes in the rarer Medium an Angle of Refraction, which has of Surplus what it had less in the denser Medium.

29. The Course which Light followed in passing out of a rarer Medium into a denser, is the contrary of the Course it follows in repassing out of a denser into a rarer. The Refraction in the first Case being in the second the Line of Incidence; likewise, what was the Line of Incidence in the first Passage, becomes the Line of Refraction in the second.

30. The Angle of Refraction is great in Proportion as the Angle of Incidence is great, and they are both diminished alike.

31. Several have very seriously pretended, and even geometrically explained the Cause of these Processes of Light, by a certain attractive Virtue, which they suppose inherent in the Surface of the most massive Mediums, so that when the Light enters it obliquely, the Direction of its Obliquity is inflected by the Attraction. Light plunges itself more into it, than it would have done in following its first Direction, and sinks when it approaches the Perpendicular: Whereas, when it comes out of the massive Element, to enter another rarer, and which has less Attraction, the Ray deflects from the Perpendicular, and inclines always towards the attractive Surface.

This

This is called leaving a Thing in a Place, and saying afterwards, that it was found there. The Geometry added to it proves nothing more. The Course of planetary Influences could be calculated and measured: These same Influences could be put in a compromise with the local Virtues, which would be attractive in one Place, and repulsive in another. The System could be embellished by changing, beyond certain Lines, the Attractions into Repulsions, and then imagine that we explain the whole Nature. Geometry countenances all Sorts of Suppositions, and puts in Order what it supposes, but does not demonstrate any Reality. It is necessary enough to observe, that Light in its Inflections, when it passes out of a Medium into another, follows a Rule contrary to that of other Bodies. A Leaden Bullet, or a Stone obliquely hurled into Water, enters it, deflecting from the Perpendicular, and comes out of it, in approaching it in the Air. It deflects from the massive and attractive Body. What becomes here of Attraction?

32. This Proportion of the Angle of Incidence, and of that of Refraction once known and determined, some Inequalities excepted, which happen when the Angles increase much, suffices to foresee what will become of the Rays of Light, or how they will be inflected in different Mediums, without searching for Cause thereof, one that is hid.

The Passage of Light into a plane Glass.

33. The transparent Bodies which Light traverses can be plane, or spherical, or plane and convex, or plane and concave, or otherwise. Let us remember that we call radiant Point, that Point whence the Rays proceed which diverge; and Focus, that towards which they converge.

Fig. 6.

34. The Light in passing obliquely from above the Object V through the Plane P P, which is a Lamina, or Plate of Crystal, is inflected when it enters it and approaches the Perpendicular. It makes an Angle smaller than that of Incidence: But in returning into the Air, on the other Side, it deflects from the Perpendicular; and the Line of Refraction in the Air, coming towards the Eye O makes on the Crystal an Angle equal to that of Incidence V. Therefore these two Lines are parallel: And if several oblique Rays are parallel between themselves while they enter, they will

will be parallel in all their Refractions, and answer their first Parallelism in coming out. But if the Line, whereby the Eye O perceives the Object, were prolonged, it would go into A, not into V. And though the Object be in V the true Place, the Eye sees it a little aside, through the Line O A, in the apparent Place A. The plane Glass makes therefore a small Variation in the Sight of Objects; notwithstanding which, it removes them but a little, because all those Lines of Light reassume, in coming out, the same Disposition they had among them before their Entrance into the plane Glass.

35. On the plane Surface of a plane convex Glass P C, *Fig.* 7. let fall the perpendicular Ray A, and its Parallel P. The Ray A, by Proposition 22, passes out of Air into the Glass, and out of the Glass into Air without Inflection. Opticians give it the Name of Axis, because it is as unmoveable, while the other Rays turn, and change Place round it. The Parallel P P following the same Direction in the plane Side, receives there no Inflection. But in passing into Air at its coming out of the convex Side, it concurs obliquely with the Perpendicular drawn from the Center C C. By Proposition 27, if it should enter the Glass obliquely, it would approach the Perpendicular by one Third of the Angle of Incidence represented by the Angle at the Vertex I. And by Proposition 28, it would deflect from it, here, by as much. The Differential Angle D leads the broken Ray into R, where it concurs with the other Ray A, at a Distance from the convex Glass, which is found to be worth a Diameter of the Convexity, or double the Radius drawn from the Center C C.

The Axis.

36. It follows from this Proposition, and the 28th, that if the Ray R takes the oblique Road R D, of the Distance of a Diameter of the plane convex Glass, while it enters through the convex Side, it will make, in entring, a less Angle with the Perpendicular, will become parallel to the Ray A, and come out perpendicularly to the Air to go into P P, without ceasing being parallel to the Axis or perpendicular Ray A.

37. If the parallel Ray P, falling on a plane Convex on the convex Side, *Fig.* 8. makes an Angle of Incidence with the Perpendicular drawn from the Center C; it approaches

proaches still more while it enters the Glass, and makes with it a smaller Angle. If it followed the same Line in coming out of the Glass, it would go to re-unite itself to the perpendicular Ray A in r, at a Diameter and a half Distance from the Convexity. But it breaks anew at its Arrival into the Air. It deflects from the Perpendicular p, more than it is inclined towards r, and is reunited with the Ray A in R, a Diameter Distance with regard to the Convexity.

38. In Consequence of what we have said here, a Ray proceeding the Distance of a Diameter R, and arriving on the plane Side, will come out parallel through the convex Side.

39. When the Glass is plano-Convex, we find by the Measure of the Angles of Incidence and Refraction, that Light, whether it enters through the Plane or Convex, whether it presents itself by parallel Rays, or tends towards it by Rays diverging the Distance of a Diameter; the Rays following very near the same respective Roads on both Sides the plane Convex.

40. The advantageous Sallies of Light out of the plano Convex, consist either in going towards the Eye by parallel Rays, or tending towards it at the Distance of a Diameter by converging Rays. There are a great many Rays variously oblique, and which could either resort to the Center, or gather together beyond it, or even become very diverging. But as these Directions are not found proper to form clean Images in the Eye, it is needless to seek after them.

In Lenticular Glasses.

We call a Lenticular Glass, or Spherule, that which is terminated by two Portions of a Sphere, as L, *Fig.* 9. The Ray we have called Axis, and which occupies the Middle of the Fasciculus of Rays supposed to fall on the Ferule, traverses it without Alteration or Inflection, when it goes directly to the Center. The other Rays are oblique, either parallel when they do not tend towards the Center, or all oblique with regard to the Convexity. Therefore they will be all broke in it twice, once in entring, the other in coming out of it, and always according to the Rule of Proposition 27. Therefore it will be no longer necessary to trace to you, in the Figures, the Perpendicular which regulates each

each Reflexion, nor the ſurd Lines which expreſs the March which each Ray would take, if it continued its Courſe; that Multiplicity of Lines occaſioning a great Confuſion.

42. The parallel Rays P P falling on a Spherule, L, *Fig*. 9, are broke in it twice, and have the Center C for a Focus

43. Therefore by Propoſition 28, the diverging Rays proceeding from the Center of the Convexity C, come out parallel as P P.

44. Thoſe which are very diverging, in proceeding, for Example, from the radiant Point D between the Lentil, and one of the Centers of the Convexity c, become leſs diverging when they come out as S S.

45. Therefore thoſe which enter it converging as S S, will converge ſtill more at their coming out, and concur towards D.

46. In a Word, the radiant Point being on this Si'e the Center towards D, the Rays come out diverging S S. If it is at the Center in c or in C; they come out parallel P P. If, on one Side, it be more diſtant than the Center C or c, they will converge more or leſs beyond the oppoſite Center.

47. All the Points of Objects are ſo many radiant Points. They have each their own proper Poſition; they have alſo each their proper Focus. Hence that Confuſion of Images which deſtroy one another in the Eye, by offering to it a Lentil beyond the Point proper to gather in a good Order Rays capable to form in it a vivid and preciſe Image.

Spherical Glaſſes.

48. The Ray P parallel to the Axis A, *Fig*. 10. paſſing through a tranſparent Sphere is broke twice, and arrives in 4, which is one fourth, or thereabout, of the Diameter of the Sphere. For P by its firſt Direction prolonged would arrive in 1: By its ſecond Direction 2, prolonged, would arrive in 3: By its new Refraction in Air it arrives in 4.

49. Does the Point of Concourſe, which is very near the Fourth of a Diameter at the Diſtance of the tanſparent Sphere, become a radiant Point? The Rays will come out parallel. If the radiant Point approaches more the Sphere of Cryſtal, they will diverge in coming out.

If the radiant Point draws back, they may become parallel in the Sphere, and come out converging, and the more it will draw back, the more they will converge.

50. The great Effect of transparent Spheres and Spherules, is to gather the dispersed Rays. On the contrary, the Effect of concave Glasses is to disperse the Rays parallel or converging; it is the Effect of the simple Concave: And the Effect is stronger if the Glass be concave on both Sides. See in the Figure 11. what becomes of the Parallel P P, and Divergings D.

51. In other Glasses, as plane Concave, in the Minisci or Lunulæ, one Side whereof is convex, the other concave, &c. Nothing else is required every where, but to apply to each Fall of the Ray on a Surface, the Difference known, which must arrive always between the Angle of Refraction, and that of Incidence.

The Vision.

52. What passes in our Eyes is but a perpetual Application of the same Rule, which in our Works, is a pure Imitation of the Rule of the Creator.

Remember what has been said*, of the three Chambers which divide the Eye. The first is full of an Humour called aqueous, denser than Air. The second is the Crystalline, a small lenticular Body, denser than the aqueous Humour, and terminated by two Portions of a Sphere, the anterior whereof is flatter, the ulterior more bent and lengthened; and the third full of a Liquor called improperly the vitreous Humour, since far from having the Density of Glass, it is much lighter and more rarefied than the crystalline Substance. When you know the Proportion of the three Humours of the Eye; you want nothing more than to see in a Figure which represents them, what regular and constant Changes must happen in a Pencil of Rays, in conducting it from one Point of the Object into the Air, from the Air into the Eye, and from Room to Room to the Bottom of it. If you place, in Thought, on the exterior Curvature of each Room or Chamber of the Eye, a Perpendicular tending towards the Center of that Curvature, you will perceive that the two last Rays, which we may be

See the *Fig.* in Vol. IV.

* Vol. IV. Dialogue viii.

contented

contented to consider among all those which compose a Pencil of Rays, in passing out of Air into the aqueous Humour, will approach already a little, and afterwards still more in the Crystalline, since they sink into those two Chambers, by making each Time a smaller Angle with the Perpendicular. They make it greater, afterwards, by receding from it, in the vitreous Humour, which leads them to the Point of Union on the Bottom of the Eye; and all Pencils thus directed by the Refractions they are subject to in the Eye, have each their proper Focus on the Bottom of the Organ. From these Foci or Points of Re-union disposed on the Bottom of the Eye, as are the Points of the Object whence the Pencils proceed, results that Image which the Mind perceives erect and single, though it is double like the Organ, and inverted on the Fund of the Eye.

53. One Thing which appears to contribute most towards rendering the Image clear and true, is the ciliary Ligaments found proper by their Distentions, Contractions, and other Motions of all kinds, to flatten, lengthen, and present different ways the Crystalline which they support, which modifies the Rays from one Instant to the other, re-assembles them sooner or later, and facilitates the Exactness of the Images according to the Desires of the Soul, though without any Knowledge on its Part.

54. The most celebrated Anatomists, and others learned, are divided on divers curious Questions, which you may undertake to explain by yourself, after you have formed a just Notion of the first Thing necessary for the Purpose. Therefore:

That there are Images painted on the Fund of the Eye, is certain; but the Dispute is on the Seat of that Image; some pretending that it is drawn on the Retina; others on different Fibrillæ. The radiant Crowns which luminous Bodies appear to be environed with, especially when we wink, proceed from the Manner several Rays fall on the Edges of the Eye-lids, and are carried into the Eye, at the Extremities of the Image. But the Manner the Thing is executed is disputed. M. *Rohault* believes that these Rays are reflected on the glossy String which terminates the Eye-lids, and send back those Rays from Bottom to Top, and from Top to Bottom, in the Eye, when the Eye-lids approach one another. M. *de la Hire* pretends this is not

done by Reflexion, but by Refraction; becauſe the Eye-lids cloſed by winking fill up the Vacuity which parts them from the Eye, and form as a tringular Priſm, the Inemal and Liquors whereof give a Paſſage to ſome Rays, and break them in ſuch a Manner as to carry them to the Extremities of the Image traced in the Eye.

Such are ſeveral other Queſtions made on the Means we have to judge of the Diſtance of Objects; in which there remains yet ſome Obſcurity.

55. We are miſtaken, perhaps, in the Party we eſpouſe on theſe Queſtions of Optics, by attributing to a ſingle Cauſe what is the Effect of ſeveral concurring ones. Here are ſome of thoſe which influence moſt the Manner of our being affected at the Sight of Objects.

1. Objects, whoſe Images are very luminous and clean, appear to us nearer. 2. They appear more remote in Proportion as the Lineaments are weakened or dimmed. 3. From each Object arrives on our Eye a Maſs of Rays, which forms as an Angle, or rather a Cone, the Baſe whereof is on the Surface of the Object, and the Vertex at the Entrance of the Eye of the Spectator. Theſe converging Rays diverge in the Eye, and become a new Triangle or Cone, whoſe Vertex is at the Entrance of the Eye, and the Baſe on the Fund of the Eye. This is not contrary to what we have ſaid of the Pencils; which proceeding from each Point of the Object, grow larger and cover the whole Pupil; then are re-aſſembled again in another Focus, and form alſo a ſingle Point in the ocular Image. We conſider no longer, here, all theſe Pencils together, but each apart as a ſingle Line. Of the whole Maſs of Pencils proceeding from the Points of the Object, we make, at preſent, but one conic Pencil of right Lines, which interſect each other at the Entrance of the Eye, where they form of their Extremities the ſeveral Points of an inverted Image, and exactly conform to its Model, ſince all theſe Ends of Pencils are ſo many Foci, diſpoſed among themſelves like the Points of the Object. Whence it follows, that the greater is the Image, the Object is moſt commonly greater: It is what Opticians mean when they ſay, the Object, ſeen under an Angle greater than the other, appears greater: This is the Foundation of the Diminutions of Perſpective. 4. It ſeems that our Judgment has a great

Part in the Manner we see Distances and Diminutions. While we are sensible that Objects are extremely enlightened and very near us, an Angle, either smaller or greater, is not our Rule. Several Persons of the same Height, appear equally tall, though at an unequal Distance in the same Room. A Window we see entire thro' a Pane of Glass of our Apartment, appears larger than that Pane of Glass, whose ocular Angle contains, notwithstanding, that of the Window. We believe we see a Cord drawn across a Room distant from us, the Window whereof is open; then viewing with more Attention our Casement, we perceive the Thread of a Cob-web which crosses its opening. That Thread carried by the Thought into an Apartment a hundred Paces distant, was a Cord; seen where it is, without minding the other Window, it is an almost imperceptible Thread. 5. The Pupil contracts or dilates itself, as much as it is needful. The Images traced in the Eye more or less large, change the Impression of the Object. A small Hole, made with a Needle or Pin in a Paper, hinders the Rays of the Weather-cock of a Church from striking the whole Pupil of our Eye, and the Image thereof diminishes, at once, by one half or three Quarters. The want of Light in the Dark, dilates so much the Pupil, that the magnified and confused Images we see, point the Objects much bigger, and sometimes frightful. When the Sun or Moon are near the Horizon, their Light is dimmed by the Interposition of a long Track of Vapours between them and the Eye. The Eye affected with a soft Light dilates the Pupil, which must render the Image bigger than when the Planet clears up in its Elevation. It must, on the contrary, appear smaller in the Telescope, because the Diaphragm of the Instrument contracts the Image, which a small Hole made with a Needle on a Paper, would still contract much more. 6. Habit, Experience, and the Concurrence of the other Senses, contribute much towards making us establish Order and Correctness in distinguishing the respective Distances of Objects. Children, for this Reason, appear to see them, but very confusedly. All was in Confusion, when a young *Englishman*, of 14 Years of Age, born blind, began to see in 1729, after he was cured by the Dexterity of M. *Che-*

selden *, who made on him the Operation of the Cataract.

The Catoptric or Light reflected.

55. The Refractions of Light in the Humours of the Eye, and different Mediums which receive it, produce Effects, the Research whereof is called Dioptric. The Effects of Light reflected by polished Surfaces give Room to another Consideration called Catoptric.

57. As the constant Proportion of the Angle of Refraction with the Angle of Incidence is the Foundation of Dioptric; the Equality of the Angle of Reflection with the Angle of Incidence is the first Foundation of Catoptric.

58. All Bodies in Motion preserve their Direction till a superior Action weakens or destroys the preceding one. Thus Light darted from a luminous Body, or reflected on an opake one, preserves its Disposition, till it be dissipated or otherwise inflected by Surfaces otherwise disposed: Whence it follows, that every Eye which shall receive in its Fund the Impression of a Number of Capillaments of Light ranged by their End as the Points of the opake or luminous Object which has directed them, will consequently see that Object.

59. That Eye will see the same Object so many times as a Mass of luminous Capillaments shall strike it in the same Order.

60. According to the Abundance of Rays, and their long or short Continuance in the same Order, the Image will be strong or weak, clear or cloudy.

61. Thus Rays which come immediately from the Sun, or Light of a Candle into my Eye, are disposed in it like those Bodies; for I have not only the Sensation of the Light, but likewise that of the Sun and Candle.

62. The Rays of the Sun or Candle reflected by the small Surfaces which are without Number on each Object, are dispersed like these Surfaces, and returning no more to our Eyes in the same Order, show no more the Candle or Sun.

* Philosophical Transactions abridged by *Eames* and *Martyn*.

63. The

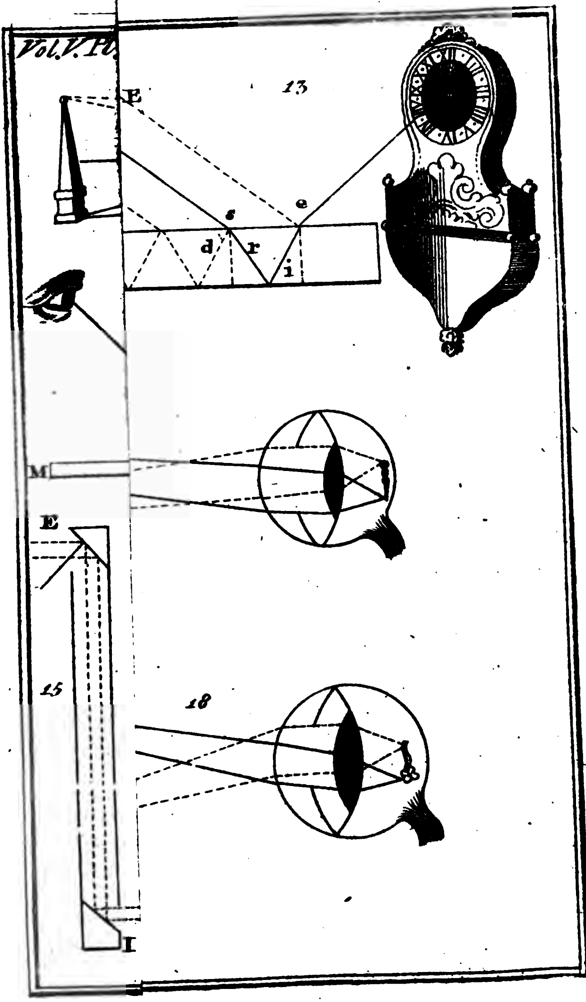
63. The Rays reflected on Objects show those Objects to us, when disposed in the Eye in a sufficient Number, and in an Order resembling enough the Picture of the Object which has reflected and disposed them.

64. The Rays proceeding from a Pendulum, and carried on the Picture of M. *Pascal*, or M. *de Fenelon*, are reflected all Ways on the Inequalities without Number of these two Pictures. The Contrivance of the Pendulum is disposed for the Eye, and receives, from the two Canvasses, Masses or Groups of Rays disposed in Order like the Features of these two, the greatest Genius's of the last Century.

65. Are the Rays which proceed from the Pendulum and the neighbouring Candle carried on the Glass of a Pastel? Then, according to the Situations in which I place myself, I see the Pendulum, Candle, Glass, and Pastel; the Flame of the Candle strongly, the Pastel neatly, the Glass and Pendulum weakly. Whence proceed these Differences? The Image of the Flame is strong, because it is a luminous Body which emits many Rays. That of the Pastel is neat, because it communicates its own Order to a great Quantity of reflected Light. The Glass is seen on all Sides, because it has yet Inequalities which reflect the Light all Ways. But the Aspect is weak; because having been polished it has lost a great Number of its Inequalities; and the more finished is its Politure, the less proper it is to show itself. It is made brown so as to appear black, and, as it were, invisible. But the less Inequalities it has, the more proper it is to reflect Light regularly on the Side opposite to its Fall. The Backing, which a good Gardener heaps up behind a File of young Plants, extending itself between the South and North, sends back on them the Heat and Light on the South Side. But if the Plant be without that Covert, and on a flat Ground, the Sun's Rays which fall at the Foot are dissipated Northward in their Resilition. Thus Light falling on a rugged Surface, finds in it, not only a Backing, but Millions of Backings, of Hillocks, and Curvatures, whose Varieties it imitates in its Resilitions But does it fall on a Surface extremely polished? Its Resilitions become then regular. The Reflection, not on all the Parts, but on a great Number of the rugged Parts, becomes then like the Incidence.

Therefore if you are placed with regard to the Glaſs, like the Pendulum and Candle with regard to the ſame Glaſs, you will receive Rays, which will be diſpoſed in their Reflection, like in their Incidence. You will ſee yet, therefore, the Candle and Pendulum; but of thoſe oblique Rays proceeding from the Pendulum, there are a great many more admitted into the Glaſs, then reflected towards your Eye; and the Image will be weak.

66. Let us take off the Picture in Paſtel; and ſpread under the Glaſs a Lay of Quickſilver, and add to it a Lamina or Leaf of fine Tin: The Tenuity of the Grains of theſe Metals diſpoſe them to fill exactly all the Inequalities or Cavities, which remained in the other Surface of the Glaſs, though equally poliſhed: The Rays, inſtead of being tranſmitted into the Air through the Glaſs, find the Paſſage ſhut by a Surface ſmooth enough to make them reſiliate eaſily under an Angle equal to that of their Fall. This Glaſs is become a Mirrour or Looking Glaſs. Let us place this Mirrour where the Paſtel was, and ourſelves towards the Right, with regard to the Mirrour, under the ſame Obliquity of the Pendulum on the other Side; ſince in that Poſition only, the Reſilition of the Rays proceeding from the Pendulum placed on the Left, can affect our Eyes, the Return being always like the Incidence. Of theſe oblique Rays few reſiliate at the Point of Incidence, and muſt produce a weak Image; the others much more numerous are received into the Glaſs, broken at the Entrance e (*Fig.* 117.) towards the Perpendicular; and the Line of Refraction becoming in the Glaſs a Line of Incidence i on the other Surface of the Fund, the whole Maſs of Rays reſiliate regularly upon it, according to the Direction or Line of Reflexion r. Moſt of them come out in s, and following in the Air the Courſe of their firſt Incidence, ſince there they recede as much from the Perpendicular as they have approached it in the Inſide of the Glaſs; they arrive in the Eye placed with regard to the Mirrour under the Obliquity of the Pendulum. The Regularity and Number of theſe Rays reflected on the Fund will give a neat Image; but is that Image which appears ſingle, really ſo? If what we have eſtabliſhed be juſt, the Image proceeding from s, ſhould be accompanied with two or three other Images, more dim or weak, one on the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the Left E, proceeding from the first Reflexion on the outward Surface, and from the Point e, very different from s; the other on the Right D R, proceeding from the last Reflexions. In fact, the broken Ray 1, and reflected on the Fund, does not pass whole in s towards F; a small Portion thereof is reflected towards d, and in this its Progression from one Surface to another, these last Reflexions become triple, and sometimes quadruple, then arrive in D R, one weaker than the other. What flows here from the Principle, is justified by Experience. For though in Day-time, we most commonly see but the Image proceeding from the Bottom r s F, which eclipses all the others by its Radiancy; if notwithstanding, instead of an Image formed by a Light reflected on the Objects, such as the Image of the Pendulum, you employ at Night a luminous Body emitting vivid Rays, you will see what I have foretold. A Candle presented obliquely, and with the Left Hand to the Mirrour, will form in your Eye, placed otherwise in the same Obliquity, a vivid Image F proceeding from the Fund. On the Left of F will be another Image E, proceeding from the outward Surface, but it will be dim, and coalesce more or less with the first F. On the right of F will be the Image of the last Reflexions D R, but weaker still than E, and repeating itself three or four Times, and always becoming weaker and weaker, as in the Figure 14. The thicker the Glass is, the greater will be the Distance between each Image. And on the thickest Glass as on the thinnest, these Images will approach one another, so as to coalesce in Proportion as the Candle takes a less oblique Situation, and at last the Reflexion of the outward Surface will be made on the same direct and perpendicular Line as that of the Fund is made. This is what appeared to me to flow from the Principle, before I had any Knowledge of the Phænomenon of the Light of a Candle tripled, as I have explained it here: And after I had traced the Figure 13, I presented the Light of a Candle instead of a Pendulum to several Mirrours, all which represented to me a strong Image, accompanied with two weak ones *. The last Reflexions follow some-

* I thought this Remark new, but I have just now found it in *Musschenbroek.*

times the principal Image, to the Number of four or five: in becoming weaker and weaker. The same Light presented obliquely to the Surface of Water poured into a Bowl should, in my Opinion, lose most of its Rays absorbed under the Surface; and the Image reflected on the Outside be therefore dim and single; which, in Fact, happens.

67. Let us lay aside, at present, the double Surface of the Glass, and see in what Point the Image, reflected by the Plane Mirrour, will represent the Object. Let the plane Mirrour be M M, *Fig.* 14. The radiant Point, or real Object O, the Point of Incidence I, the Line of Reflexion R, the same Line of Reflexion prolonged indefinitely P. It is in this lengthening of the reflected Ray R P, that the Eye will see the false Object or Image of O, and will see it in a Point of that Line as much distant from the Incidence I as is the Point O: Therefore the Eye will see the false Object in F and placed beyond the Mirrour, as the real Object O is placed this Side the Mirrour. The Position of the imaginary Focus F is found by a Perpendicular drawn from O into M, and prolonged so as to concur with R P in F, thus forming on either Side equal Triangles, where the Focus F answers to O.

68. If we place two Glasses near one another, and upright on the same Plane, the Object will be painted on them as on a single Surface, though half of it on one of the Glasses, and the other half on the other Glass, according to the Manner the Object appears before them; and the Separation of the two Glasses will traverse the Image without rendering it irregular. But if several Mirrours, or Fragments of Mirrours, make together different Planes, or one of them a lesser Angle with regard to the other, there will be then as many Images as there are different Pieces of Glass. For the Images are multiplied like the Reflexions, the Reflexions like the Incidences, and the Incidences like the Planes.

69. The convex or concave Mirrour, being a Portion of a convex or concave Sphere, and having therefore so many small Planes as it has Points, should in all Appearance give as many Images as there are Planes and Perpendiculars variously inclined: But these Planes are infinitely small: Their Field is so little, that all they can do is to reflect the Image of a Point. But by their diverse Inclinations

clinations they disperse or collect the Rays proceeding from the different Points of an Object, so as to form Figures sometimes greater, sometimes smaller, sometimes distorted, and sometimes romantic, the Causes whereof are found in the Combinations of the Circumstances to which the Principle of the Equality of the Angles of Incidence and Reflexion can be applied.

70. Present a Figure or lucid Body to a spherical Glass, whether convex, or concave, or cylindrical, or of any other Curvature: According as this Object recedes from the Center, or approaches it, or places itself between the Center and Mirrour, or shows itself more or less obliquely, there results from it Dispersions of Rays, of Parallelisms, of different Foci, of Inversions of Images, of diminished Figures, of Figures monstrously magnified, sometimes distorted, and in Appearance romantic. If, for Example, the Forepart of a Mirrour be plane, and the other Side convexed and silvered, this Disposition renders it concave for the Light. If you place yourself between this Mirrour and the Center of its Curvature, you will see all your Features extremely magnified, because the Rays, which fall diverging on its first Surface, arrive still more diverging on the Surface of the Fund, and return to the Eye under a greater Angle. And this increases the Field of the Image. If you present a Candle to this Mirrour, you will see two Candles in it, often three: One of them in its own Length, which is that reflected on the exterior Plane; the second very large, and better marked, which is that proceeding from the Bottom under a greater Angle; and a third, which is still larger, but weak and cloudy, because it is that of the last Reflexion from one Surface to another. If you put the Eye at the Center of the Curvature, all the Rays emitted from the Eye are perpendicular to the Concavity, and the Resilition being as the Incidences, the Rays will return to the Perpendicular, and you will see only your Eye. Opticians have followed gradually these Figures, and demonstrated that they were all the necessary Effects of the two Principles of Reflexion and Refraction, differently combined, and applied according to Circumstances. These Researches have procured us various Effects of Light, which surprize when we do not know the Cause of the Extension, Inversion, or Contortions which

happen to the Images of Objects according to the various Processes of Rays. Hence very small Figures prodigiously magnified in the magic Lantern, by the great Divergency of the Rays. Hence those rough Draughts, or Cartoons, loaded with confused Strokes or Touches, which, being exposed before a cylindric Glass, throws on that polished Column a Figure of a gracious Attitude and perfect Regularity. But as we search here Effects of some Utility, rather than puerile Inventions, which serve only to amuse or divert us, we will pass to the Instruments which Opticians have invented, and the Succours Man receives from them.

71. Mirrours and transparent Glasses, the Concave, the Lenticular, the Spherical, and others, serve apart, or together.

72. Every one knows the Use of the plane Mirrour. As it carries within itself the most perfect Imitation of Nature, if, in a Closet, which makes the Angle of a Building, you oppose one, or several Mirrours in their Frames on the same Plane, in form of Glass Windows, to a Ribble-row of Rooms, that Ribble-row is seen double. If your Mirrours receive the Aspect of a Garden or fine Country, all these fine Prospects are agreeably repeated.

73. By the different Manners of opposing a Mirrour to another, you obtain not the simple Repetition of an Object, but a Multiplication of the same Images, reproducing themselves in immense Distances, and almost beyond the Sight. To have a slight Notion of the Possibility of these Reproductions, place a Candle between two Mirrours; the naked Light you see paints itself on the Mirrour placed on the Right. That Image is reflected on your Eye, and on a Point of the Mirrour of the Left, where it forms besides a double Reflexion, *viz.* on your Eye, and on the Mirrour of the Right. Here is a new Distribution semblable to the preceding one, but weaker. Here are, therefore, already four or five Images produced by the Fall of the Image on the Mirrour placed on the Right, and of its different goings and comings. To these four Images, join as many others produced by the Fall and semblable Progresses of the same Image on the Mirrour of the Left. This is conceived without the Assistance of a Figure: You'll have different Effects, or more numerous, if you change the Position of the Mirrours, or multiply their Planes: These Combinations are without End.

74. Con-

74. Conceive a Tube which has a lateral Aperture in E, and another in I. (*Fig.* 15.) Over-against each Aperture place a plane Mirrour, inclined 45 Degrees, or half a right Angle on the Fund. The Perpendicular, which is to fall on the Surface of the Mirrour, will form two right Angles. The external Rays falling parallel at the Foot of this Perpendicular in E, and forming with it an Angle of 45 Degrees, will reflect along the Tube under such an Angle. They will renew the same Play on the other Mirrour placed in I, since it is the same Inclination, the same Incidence, and the same Reflexion. In a Camp, or a Place besieged, you may use this Instrument. From within a Tower, or behind a Parapet, put out the End E by turning the lateral Aperture on the Side you want to see in the Neighbourhood, and applying the Eye in I, you will be able to discover, without Danger, whether the Miner be at the Sap, or the Motions of the Enemy. For this Reason this Instrument has borrowed the Name of Polemoscope. If, from within your Closet, you want to see the Motions of a public Place, situated sidewise, the Aperture E, directed towards the Merchants who are quarrelling, will shew you in I Attitudes full of Warmth, and very expressive Gesticulations.

The Polemoscope.

75. The Position of this Mirrour, inclined 45 Degrees on the Bottom of the Camera Obscura, portative at Pleasure, disposes all the Rays received through the lateral Aperture, to re-ascend in a right Angle towards the Top; since two Angles of 45 Degrees each give together ninety Degrees. The Rays or Pencils carry their Extremities, on a Piece of Vellom braced tight, where they range themselves like the Points of the Objects. This Instrument exhibits Images perfectly like their Objects; and by its Means you learn to delineate Objects to the last Accuracy and Justness, by copying Attitudes of a great Truth.

The portative Camera Obscura, *Fig.* 16.

76. These Instruments are rendered perfect, by adding to the Aperture which receives the Rays, one, or several Tubes, which can be pushed back, or drawn forward; and in one of them is fitted a lenticular Glass, proper to disperse a superfluous Light, and strengthen the Picture you want to see.

Fig. 16.

77. The

The lateral Spying Glafs.

77. The inclined Mirrour, feconded with a good Lentil, or a Concave Glafs, for fome particular Eyes, is the whole Artifice of the lateral Spying Glafs. It is directed always, not quite oppofite to the Perfons we want to fee more diftinctly, but pretty far from them, and fideways; which is lefs rude, than to point the Spying-Glafs quite point blank, to ftudy the Face of Perfons.

78. An Engraver who copies a Draught, finds it, in the Impreffion, difpofed the contrary Way. The Figure of a Gentleman is feen with the Sword on the Right Side, or the Hat under the Right Arm. But a Mirrour placed by the Draught, makes a firft Tranfpofition; and the Impreffion, which gives a fecond one to the Figure, made with the Affiftance of the Glafs, reftores it to its right State.

79. Some firft Lines traced, and prefented to Mirrours, the Faces whereof form Angles more or lefs open, facilitate the finding foon Cartridges of an agreeable Contour, very neat Cyphers, Cieling-pieces, and Compartments of Parterres, and Embroidery, which, otherwife, had never been imagined.

80. In a Mirrour, even but of a fmall Field, we fee the Objects, and Perfons in their natural Height. A Limner, who wants to imitate them, places before its Mirrour a Frame divided into fo many fmall Squares of Thread, as he has drawn great ones on his Canvas; he obferves carefully, on what Angle, on what Line, arrives a Finger, an Elbow, a Shoulder, or any other Object ranged by its Mirrour. All the Parts of the fmall and excellent Picture furnifhed by the Mirrour, are transferred in great, and in the fame Order on the Canvas. The Mirrour helps therefore towards the juft Pofition, and moft delicate Proportions of Figures. It is a fure School for learning Situations, Miniature, and Perfpective.

81. Perfons who have the Cryftalline too flat, a Defect which happens by Degrees, with Age, cannot fee diftinctly but remote Objects; becaufe, when the Object is near, the Rays are too diverging. They continue to be fo in the Eye, and the Cryftalline does not collect them but beyond the Bottom of the Eye. Then the Foci of the Pencils are not difpofed on the very Fibres where the Motion

of

of the Picture is to be made, but when the Object is removed at some Distance: and a thin Lentil, capable to facilitate the Collection of the Rays, and make them concur not beyond the Eye, but precisely on the Fund, is interposed between the Eye and the Object.

82. Those who are near-sighted have the Crystalline too convex. When they receive at some Distance Rays which are but little diverging, and are re-united by a too convex Crystalline, in some Points of the vitreous Humour, the Image of that Focus becomes needless: The Rays cross each other in it, and proceed to cause a confused Motion on the Bottom of the Eye. The Remedy for this Inconveniency, is to draw the Object nearer; because Rays which enter the Eye at a great Angle, and very diverging, are not so soon collected; but, when the Object is drawn nearer the orbicular Figure of the Crystalline, direct the Rays into Foci, which form a neat Picture just on the Bottom of the Eye: Or else a Pair of concave Spectacles is placed between the Object and the Eye, which Spectacles disperse, and make the Rays diverge so as to exercise a propos the great Convexity of the Crystalline.

Concave Spectacles.

83. Perhaps Optics serve us as well by good Advices, as by good Instruments. We approve the Method of employing but a moderate Light in the Use of the Eyes. By Means of this habitual Precaution, and taken while young, several Persons have seen without Spectacles when they were very old. Could the Eye be like the Stomach? which is hurt by a too great Plenitude, and most commonly the more it is filled the more it craves: And, when used to it, the least Diminution of Food makes it suffer; hence puny and weak Stomachs.

84. By means of the Principles already established, you may conceive the Effects of a concave Spying-glass, and of the loupe Convex on one Side, or both. A lighted Candle will emit as many Pencils of Rays as it has Points, which received in a too convex Crystalline, dispose their Foci in the vitreous Humour, which forms a confused or lost Image. To carry that Picture as far as the Bottom of the Eye, the concave Spying-glass D E, (*Fig.* 17.) is opposed to the Rays. Let us follow in it the Course of the two

The concave Spying-glass.

Pencils

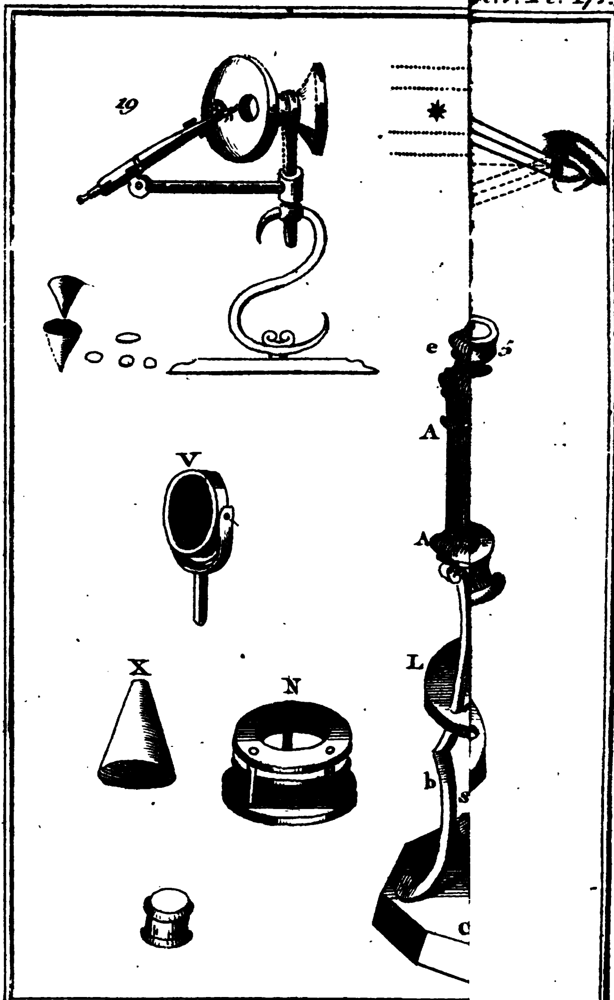
Pencils C B; they will regulate the Fate of the others. The two external Strokes of the Cone proceeding from C, will approach the Perpendicular in the Thickneſs of the Glaſs, and recede a little from it in the Air. They go to paint the Light of the Candle in the Bottom of the Eye, and thoſe proceeding from the Foot of the Candleſtick B paint it on the Top of the Eye. The Figure being there inverted, the Object will be ſeen erect; which is the Law of Nature. But, when the Eye ſees by means of Rays which have been inflected, it does not direct them to their true radiant Points C B, but to the imaginary Points I H, where they ſeem to concur. Now the Field I H is much ſmaller than C B: Therefore the concave Spying-glaſs diminiſhes the Image; but this Image is neat.

The Loupe.

85. The Fields muſt extend the contrary Way in the Loupe A B, (*Fig.* 18.) The Rays proceeding from the two Petala of a Flower F E, which you keep between the Center G and the Loupe, diverge on the Glaſs, become there almoſt parallel, and invert the Object in the Eye; whence it follows that it appears erect. It is painted in it as if the Eye was naked. But as the Rays have been broken in the Glaſs, the Eye ſees the Object, by means of the Strokes which affect it, as prolonged and radiant in M N, the Field whereof is greater than in F E.

The ſimple Microſcope.

86. The ſimple, or ſingle Microſcope, whoſe Baſes, and ſubſidiary Implements may be ſeen in *Joblot*, conſiſts of a ſingle Lens or Ferule, whoſe Convexities are the Portions of a very ſmall Sphere, or rather, is but a very ſmall Sphere of white Glaſs. We have obſerved, that the parallel Rays, which enter a Sphere, concur, and form their Foci towards the fourth Part of the Diameter; a very ſmall Diſtance with regard to a very ſmall Sphere. If, therefore, the ſmall Object be placed in that Point, very near the Glaſs, the Rays will fall upon it very diverging, become ſtill more diverging in the Glaſs, and carry into the Eye a Cylinder of parallel Rays, much larger than the Object. The Angle of the Image formed in the Eye by the broken Rays will be regulated on the Breadth of the Cylinder, or Maſs of Rays received in the Eye. The Object therefore will appear much bigger than it is in Reality; and likewiſe appear



The Rays fallen parellelwise on the Focus of the Spherule. This Microscope perfes C..9.

appear erect, because the Eye acts here, as it does naked. It bends downwards the Rays proceeding from the Top of the Object, and upwards those from the Bottom, whereby the Image is inverted; which is the only Means to see it erect.

87. The Necessity of approaching a very small Object near this Glass, fitted to a pretty thick Base, brings the Object exactly under the Shadow, and hinders the Image from being easily seen. Let us lay aside all the imperfect Means used till now to remedy this Inconveniency, and come immediately to what has been found most easy and efficacious, to have a Light fully reflected on the small Object: It is the Microscope of M. *Lïberkhun*, a learned *Prussian*, who had the Complaisance to communicate it to us, and shew us the Structure thereof.

The Microscope with a perforated Mirrour. *Fig.* 19.

A wooden broad and flat Pedestal, an S or Silver Sconce, with a Screw, to be taken to Pieces and laid flat, with the Pedestal, in the Pocket; a Pillar, and little Tongs, are the whole Support of this Microscope, which has nothing extraordinary. Two very small Funnels of Brass or Silver, which have each, at the Vertex or Top, an Aperture smaller than the Body of the globular Glass to be fitted to it; a concave Mirrour of Silver, in the Form of a Chalot, of an Inch or less Diameter, well polished Inside, and perforated in the Middle of its Concavity to receive with the Fastenings, prepared for the Purpose, the Nipples of the Funnels: Such is the Body of the Microscope. The Object disposed at a very small Distance from the spherical Glass, and at the Return of the Light, does no more shadow itself, but offer to the Eye a Surface well illuminated: There is a just Proportion between the circular Figure of the Mirrour, and the Smallness of the Lentil, to make the Fall of the reflected Rays concur with the Position of the Object. But, was the Situation not quite so perfect as it might be, the Light brought from all Parts, and especially the Top, resiliates several Ways on the Politure of the Mirrour, and is always abundantly enough reflected on the Object, to render the Image thereof as neat as it can be magnified by the Bigness of the Angle.

88. By

The reflecting Microscope with three Glasses.

88. By composing the Microscope of several Glasses, we have searched to magnify still more the Image; to distinguish better the little Animals which flutter in several Liquids; to discover better the nutritive Vessels, and Characteristics of the Parts of the vegetative or animal Body. We will set aside a hundred Sorts of these Microscopes, to mind none but that which has three Glasses, with a double Reflexion. Let us begin by the Progress of the Rays. In *Fig.* 20, S S is the Portion of a concave Mirrour placed at the Bottom of the Microscope. The parallel Rays R R are obliquely reflected in it, and concur in a Focus of some Extent A B. Here the Object is placed. From this Point, which is very near the Center of the Curvature of the objective Ferule C E, the Rays pass into the Ferule, come out almost parallel, are received in the Ferule h g, which has been kept very large to take them in without Loss; from hence they pass into d f, where they concur in Foci, or Points of Pencils disposed between them, like the Points of the Object, but more in great. You must observe, that by the Transposition of the Rays, this Image is inverted. From this Image, as from a real Object, sally Rays to arrive obliquely in n k the third Ferule, called Ocular, whence they come out parallel between them, and go to paint in the Eye the Image d f, whence they sallied last. This Image is inverted; that in the Eye is erect like the real Object, therefore the Object will appear inverted. This Description is the Skeleton of the great reflecting Microscope. Let us see the Body, and Use thereof.

Fig. 21. *Baker*'s Microscope made easy.

A A A A, The Body of the Microscope supported by three Brackets b b b, on a small Trunk or Supporter C, containing the Drawer D, wherein the Ferules, and other Instruments of Use, are kept.

e e The Tube which slides into the Body of the Microscope; it carries in its greatest Breadth the great Ferule, and goes diminishing towards its two Extremities. In the upper Part it carries the Eye-glass, and the lower Part f finishes by a Screw g, appointed to receive the Ferule, wherein the Object-glass is fixed. The Drawer contains five of them, which magnify unequally. The Tube e e, ascend-

ascending and descending at Pleasure, helps towards finding the Point which suits the Eye of the Spectator.

L, a little square Brass Head, perforated in M to receive the Slice-bearer N. This Instrument N is composed of three Circles, two at Rest, and one moveable. There are sliden horizontally into it long slices of Ivory, such as 4, wherein the small Objects are inclosed between two Leaves of Talc of *Muscovy*, very transparent, and kept in their Lodge by Means of a small Ring of Brass with a Spring, which Ring keeps itself in its Place. The Slice 4, which moves backward and forward at Pleasure, becomes firm when let go, because the moveable Circle which carries it, is itself driven against the upper Circle, with the Assistance of a Steel Spiral.

O, a small Plate perforated with several Holes, to receive several small Objects, enclosed as above, between two Leaves of Talc. One of these Holes is shut with a concave Glass, to receive some Drops of the Liquor, wherein has been macerated, either Straw, Hay, or other Things of that Kind, to decoy small Animals into it; two others of these Apertures are stopt, one with a Slice of Ivory, to render the Colour of opake and dark Objects more apparent; the other with a Slice of Ebony, to facilitate the Distinction between clear and opake Objects. The Nob in the Middle of this Plate slides and stops in P, to become there a Pivot, on which the Plate turns, and brings the Object wanted on the Aperture M.

K, a concave Mirrour turning on the two Trunnions S S, in the Semi-circle R, which turns itself on the Pivot c. By means of these free Motions, the Reflexion of the Light, or Sky, or Candle, is thrown on the transparent Object fixed in M. This first Reflexion can serve by Day-light and Candle-light.

V, a Lentil convex on one Side, and plane on the other, to throw from some Distance the Light of a Candle, and collect it in a quick Focus on the opake Object placed in M. This Lentil, or Spherule, plays like the concave Lens or Mirrour, and inserts its lower Pivot into the Aperture W; this Reflexion is the second, and of very little Use by Day-light.

X, a hollow Cone of black Wood, to be placed under the Aperture M, when Spherules, which magnify much, are

are used. We learn from Experience, that the Image of a transparent Object becomes more distinct by dispersing the Rays brought obliquely by the Lens, when those Rays do not concur towards the Formation of the Image.

Y, is a bent Plate, whereon is fastened a small Fish, as a Gudgeon, Smelt, &c. whose Tail being transparent, is placed on an Aperture over against M, whereby the Circulation of the Blood is seen. We can, with the same Intention, introduce the Foot of a Frog, or of a Lizard, or a small Eel alive, into the Tube I, and slide it under the Aperture M. The Circulation appears, here, much more rapid than Nature; the Object appearing bigger than Nature. If the Space occupied by the Object appears a hundred Times bigger, the Blood which traverses that Space must appear to run a hundred Times swifter.

2. Is a Lodge which carries either a plano-concave Glass, or any other, as Occasion, or the Taste of the Spectator requires it. This Lodge is placed on the Aperture M; and the Object on the Concave, which dissipates those of the reflected Rays which might be superfluous.

3. A Needle pointed at one End, and armed at the other with Tongs, which open when pressed, and shut when let go. It lies in Z, and presents the Object in M.

5. An Ivory Box, containing a Provision of Leaves of Talc.

b, A Brush. 7. Other Tongs.

Though this Microscope, which is of M. *Edward Scarlet*, and I have made Use of during several Years, be very good; I must confess, that the great Microscope of M. *George*, Optician at *Paris*, such as that he has made for M. *Duhamel*, of the Academy of Sciences, is much superior to what comes from *England*, either for the Beauty of the Effects, or for the Freedom of the Situations which multiply the Effects. This Microscope is, particularly, the most useful for transparent Objects. It is very good for the opake, with the Assistance of the second Reflexion. But to study easily the last, we return always with Pleasure to the concave Lens of M. *Liberkhun*.

Astronomical Telescope.

89. The Astronomical Telescope, and that put double at the Graphometer, has but two Glasses. By receiving the Rays of distant Objects, it modifies them as if they were parallel; they

go

go, therefore, to meet in their respective Foci, and are disposed among them like the Points of the Object, somewhere between the two Glasses. The Distance of the Focus is the greater, as the Curvature of the Object Glass makes Part of a greater Sphere. The Image being inverted at the Focus, is erect in the Eye. The Object, therefore, appears inverted. The Neatness of the Image, and Whiteness of the Light, makes us not mind this Inconveniency in Astronomy, where it signifies little whether a round Planet is seen erect or inverted. Neither is the same Inconveniency troublesome in the Measures taken on the Ground, where we want, only, a fixed Point in the Image erect or inverted. It is also considered as nothing in the composed Microscope, where nothing else is minded but the viewing a very small Object, whose Situation is indifferent. But it happens otherwise in the Land Telescope, which taking in a pretty large Field, and a Number of Figures grouped as in a Picture on a common Ground, must represent them in their natural Form, and in a Situation easy to be known.

The Land Telescope.

90. The Land Telescope consists of four Glasses. Its Figure alone will shew you the Progresses of the Rays in it, and the Inversion of the last Image in the Eye, which is the true Erection thereof.

The Construction of this Instrument consists in several Tubes of Past-board, sliding within one another, unless it be made all of a Piece. The first Tube contains two others, which are not drawn when the Spying Glass is used. Of these two Tubes, one, which is very little, carries the Eye-glass; the other longer, carries, besides, two other Glasses, called Eye-glasses also, or second and third Glass. The last of the great Tubes carries the great Glass called Object glass. The small Circles or Diaphragms placed in the Intervals of the Glasses, which are their common Focus in the Inside of the Tubes, serve to absorb the Ray which might dim the Image.

91. These Telescopes have three great Inconveniences. 1. The Multiplication of the Glasses renders the Light dim, by the Loss of the Rays which reflect on the four Glasses. 2. The Rays variously coloured in the Light itself,

itſelf, as I heretofore explained it to you*, are unequally broken, eſpecially in Proportion as they become oblique; which is the Occaſion that the Edges of the Images are dimmed by Rain-bows or Franges variouſly coloured. 3. The Length, was it but of ſix or eight Feet, renders the Diſpoſition thereof difficult. They are folded on the Length, and you loſe the Object. Their Supporters, and Movings from Place to Place, are cumberſome. Here is a ſmall and light Teleſcope, eaſily managed, and which, if only fifteen or ſixteen Inches long, is equivalent to one of eight Feet; and to another of eighteen Feet, if it has but two Feet and a half. This Teleſcope was invented very near a hundred Years ſince by a *Scotch* Optician †, who had it engraved and publiſhed in 1663. It has been improved ſince, and is found the beſt for common Uſe, eſpecially after the different Degrees of Exactneſs and Facility, the Artiſts of *London* and *Paris*, by a Motive of Emulation, have added to it. We have all its Dimenſions in a very good Treatiſe of M. *Paſſemant* on the Conſtruction of this Teleſcope, and on the Manner of grinding the Glaſſes and Mirrours. This ſkilful Artiſt leaves us Room to hope for new Productions of his Induſtry.

Fig. 23. A Teleſcope with a perforated Glaſs. You find at firſt Sight, that it conſiſts of ſeveral Pieces eaſily diſtinguiſhed. 1. Of a very ſimple and commodious Pedeſtal, and which can be taken to Pieces. 2. Of a Knee which helps towards moving the Teleſcope all manner of Ways. 3. Of Screws; ſome of which ſtrengthen the Knee, and the others faſten the Teleſcope to its Pedeſtal. 4. A Braſs Tube covered with Shagreen, thirteen Inches long, and two broad, or a little more, Inſide. 5. Another little Braſs Tube, three Inches long, and hafted with the long one. 6. A Steel Rod terminated by a Nob towards the ſmall Tube, and leaning along the great one.

The Uſe of the Pedeſtal is obvious. The ſmall Tube has but one Aperture of a quarter of a Line, to apply the Eye to it. The outward Extremity of the great is all open

* Vol. IV. Firſt Part, Dialogue ix.

† Optica promota Jacobi Gregori.

to

to receive the Parallel Rays which come from distant Objects. These Rays fall to the Bottom of the great Tube where they find a concave Glass perforated in the Middle of an Aperture of six Lines. This Glass receiving the parallel Rays on its Concavity, sends them back obliquely and collect them again in a Focus nine Inches distant, where they cross each other, and go, in diverging, to fall on the Concavity of another Glass, of eight Lines Diameter, and eighteen of Focus. They find the polished Surface of this Glass in the Middle of the large Tube at eighteen Lines Distance from the preceding Focus, and eighteen Inches and a half, or thereabout, from the perforated Glass which the small one faces. The small one is supported in the Vacuity of the great Tube on a Cursor or Arm which plays on the Outside, by Means of a Female and Male Screw which terminates the Iron Rod. The Spectator turns the Knob which Way he pleases, and makes the Cursor with its small Glass go backward or forward, according to the Distance of the Objects, or the Disposition of his Eye. The Rays, after they have crossed one another at the common Focus of the two Glasses, and fallen obliquely on the Cavity, resiliate on Lines very near parallel, which direct them towards the Aperture of the great Glass. They cross this great Glass, and meet under a light Obliquity at the Entrance of the second Tube, a first Glass plano convex, which collects them, and forms of them a second Image towards the Middle of the Tube, and on this side its proper Focus. The Darkness of the Sides of the Tubes, and a Diaphragm placed towards the Combination of the Pencils, make an End of clearing the Picture thereof; and as it erects the preceding one, the Rays, darted from it as from the Object itself, will go through a second Glass in the Form of a Lunula, to reach the Aperture of four Lines, and form in the Eye an inverted Picture; whence it happens that the Objects appear erect, and in their natural Position. The parallel Rays, darted from the Lunula will exhibit the Object as situated in the Place whence they seem to have sallied, *i. e.* towards the neighbouring Diaphragm. Thus very distant Objects appear extremely approximated.

This Telescope has occasioned that of *Newton*, which is posterior, and is a Copy of it, with few Alterations. Like

the

the former, it receives the Light through a large Aperture on a great Glaſs which lines the oppoſite Fund: Like the former, it throws it back on another Glaſs. But the Glaſs which terminates the Tube is not perforated, and the ſmall Glaſs, inſtead of facing the preceding one, looks on it with an Inclination of 45 Degrees; which brings the Light back almoſt at a right Angle, and at one of the Sides of the Tube where the Eye imagines to ſee before it the Objects which are ſideways.

This Teleſcope renders the Image very clear, and is of a very fine Invention: But the Multiplicity of its Pieces, which I omit mentioning here, joined to the Difficulty of ſeizing the Object which muſt be ſearched ſideways, in groping along, has rendered the Uſe thereof very little common, and its Deſcription very little neceſſary.

The Perſpective.

The great Number of Artiſts continually employed in Painting, or Delineating, are alſo indebted to Optics for the Rules of Perſpective, ſo proper by their Simplicity and Certainty to help the Genius, and give to the different Parts of a Whole the reſpective Situations they have in Nature. They fear nothing ſo much as to miſs the fine Nature: They have it always before their Eyes. But theſe ſkilful Copyiſts do not place a Point, but Perſpective puts in their Hands a Line which carries infallibly that Point to its proper Place.

Concluſion.

We will not carry to a greater Length this Summary of the uſual Sciences, ſince it ſuffices to render evident the Deſtination and right Uſe of the Intelligence Man has received from God. His Knowledge is viſibly that of a Governor who preſides or commands, of a Tenant that reaps, of a Maſter who diſpoſes of all. But the Structure of the World, and of all its Parts, the Knowledge of God's Deſigns, and Will, is the Science of the Creator: He has reſerved it to himſelf. Reaſon, with regard to this, is in the Dark: It knows no more the Beings in themſelves, than the Brain where it lodges; and what he is permitted to know of the free Works of God's Will, he muſt receive it from his munificent Hands.

End of the Fifth Volume.

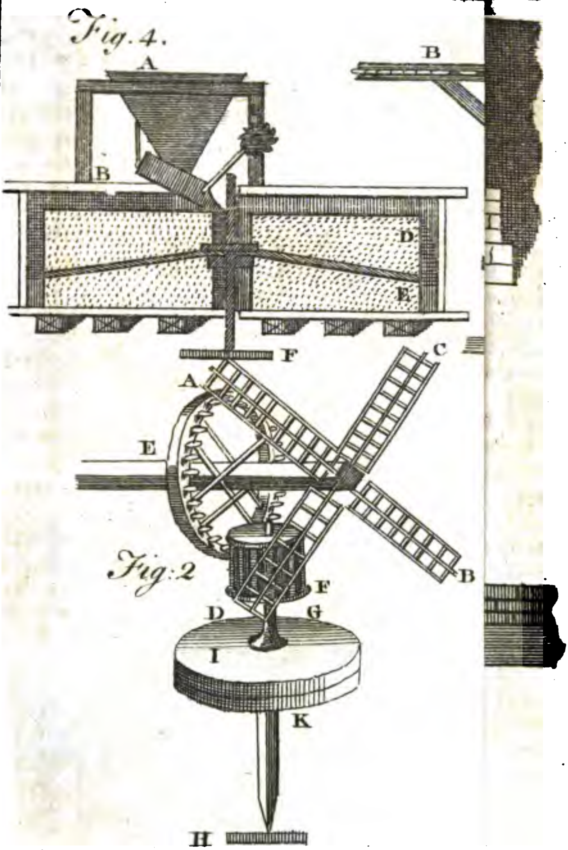


Fig. 4.
A
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B
D
E
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C
A
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Fig: 2
B
F
D
G
I
K
H

AN

EXPLANATION

OF

MACHINES

Referred to Page 224.

PLATE VI.

Mills to grind Corn.

FIG. I. A Water Mill.

A The Plane of the Wheel.

B The Arbor.

C C C The Ladles of the Wheels, Boards placed on their Thicknefs, and tranfverfly to the Circumference of the Wheel, to receive the Impulfion of the Water on their Surface.

D The Flood Gates, Wooden Gates raifed to let the Water pafs, and lowered to ftop it. The Flood Gate is ftopped at any Point, by the Infertion of a Peg.

E The Water ftopt at a convenient Height to gain, by its Fall into the Bafon or Channel F, a ftronger Impulfion againft the lower Ladles it meets with, and which

it drives with the Radius which muffles the Arbor or Axle-tree Play.

a The Profile of the ſame Wheel, with its Ladles. It has about ſixteen Feet Diameter, reckoning as far as to half the Ladles.

b The Arbor, about eighteen Feet long, and eighteen Inches Diameter. *c c c c* The Ladles.

d d The Pinions which ſupport the Arbor; they have one Inch and a half Diameter.

e The Cog-wheel, which has four Feet of Radius, and forty eight Pins implanted perpendicularly to the Plane of its Circumference, to catch the Spindles of the hinder Head.

f The Trundle Head about a Foot and a half Diameter, compoſed of two round Plates, one at Top, and the other at Bottom, with nine Spindles which form its Circumference. It is traverſed by the Iron Axis *g*, which raiſes its Point on the Piece of Wood *h*, and ſupports the ſuperior Mill Stone. This Piece of Support is called the Yard.

i The Drain where the Mill Stones are incloſed.

Water Mills are either fixed and ſituated on the Current of Water, or moveable and placed on Boats. Theſe have the Wheel directly oppoſite to the Stream, or moſt rapid Current of the Water. To drive thoſe which are fixed, the Water is ſtopped to make it fall afterwards under the Ladles into a deep and narrow Channel, that, being contracted and accelerated in its Fall, it may lay its whole Strength on the Ladles. When the Current is weak, the Water is let fall, not on the lower, but on the upper Parts of the Wheel, which in that Caſe is leſs, and carries, in its Circumference, not Ladles, but Troughs, or ſmall Sinks, the latter to receive the Action and Weight of the Water, the Strength of that Water increaſes according to its Rapidity, and its Rapidity according to the Square of the Spaces over-run. If the Water ſtrikes the Trough but at two Feet below the Mouth of the Channel, thro' which it flows, the Square of two being four, it has, in falling into the Trough, four Times more Strength, than at a Foot below its Sally*.

* See *Nature Diſplay'd*, Vol. IV. Second Part, Dial. VII.

The

The Mill with Ladles executed at *Fere* in *Picardy*, under the Direction of M. *Belider*, ground in twenty-four Hours 1340 Bushels of Corn.

FIG. II. A Wind Mill, without any Proportion observed in its Pieces. It is a first Draught, which will be cleared in the Sequel. A B C D The Sweeps. E The Cog wheel. *f* The Trundle Head. *g* The Axis. H The Yard. I The upper Mill Stone, suspended in Equilibrio to the Iron Axis. K The unmoveable Mill Stone.

FIG. III. A Hand Mill.

A A long Lever for the Motor to lay hold on. The Motor may be either one or several Men, or a Horse, or an Ox, *&c.* The Lever can be double or Quadruple, so as to receive several Horses to drive several Mills at once. B The Cog-wheel, placed horizontally, with its Pins implanted, not on its Plane, but on the Outside, and at the Circumference of the Joints. C The Trundle Heads. D The Yard. E The Iron Axis. F The Drum where the Mill Stones are inclosed.

FIG. IV. A Section of a Mill Hopper, and of the Drum which covers the Mill Stones.

A The Mill Hopper, wherein the Corn is thrown. B. The Spout of the Mill Hopper, which is a small Trough bowed to receive the Corn which fly through the lower Orifice of the Mill Hopper, and convey it into the Aperture of the upper Mill Stone. C The Iron Axis, which being square at the Meeting of the Spouts, cannot make a Revolution without striking with its four Corners against the Spout, which gives Way to the Passage of each Angle, and falls again four Times on as many flat Surfaces which are between the Corners of the Bar. Those small Jerks make the Corn of the Spout to slip between the Mill Stones, and successively that of the Bottom of the Mill Hopper to run out, being no longer kept up. D The moveable Mill Stone. E The unmoveable or fixed Mill Stone. F The Yard, the Trundle Head, the Iron Axis, and upper Mill Stone, are fastened together, and march in Company; the Axis traverses the lower Mill Stone, and plays freely in it. There is a small Distance between the two Mill Stones, they do not touch one another; and to render the Revolution of the

that it was yet in a Maſs with the Bran; the Corn being very little more than ſplit.

PLATE VII.

FIG. I. A Wind Mill, with its Sweeps and Sails, delineated by M. *Leander*.

FIG. II. Plan of the Foundation, and of the firſt Story, with the Stairs and the Handle.

FIG. III. Plan of the ſecond Story, which bears the Mill Stones and Hopper.

FIG. IV. Plan of the third Story, where the Axis of the Sweeps or Yards, and Cog-wheel, are placed.

PLATE VIII.

FIG. I. The Inſide of a Wind Mill, ſeen in Front.

FIG. II. The Inſide of a Wind Mill ſeen ſideways.

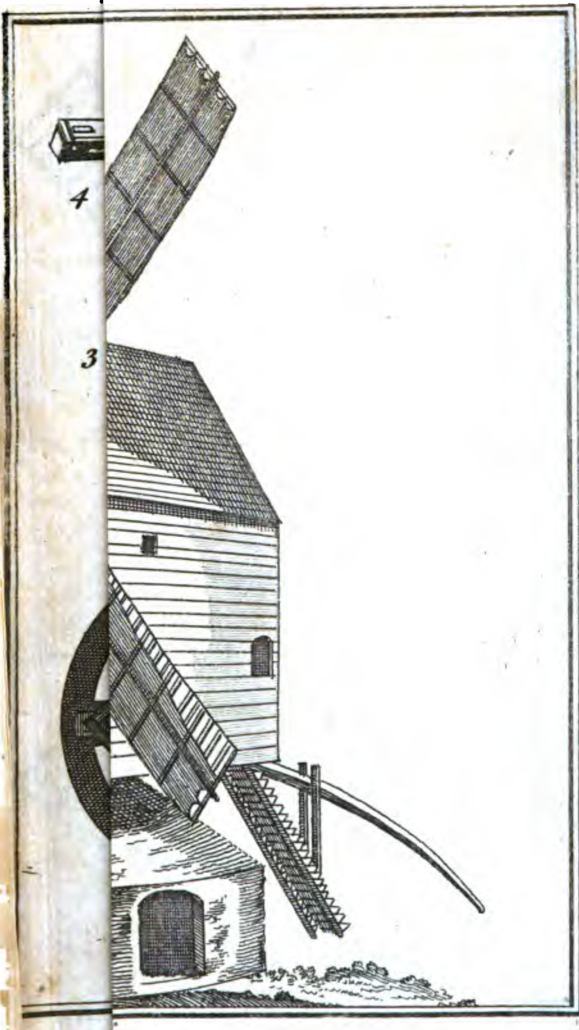
In both theſe Figures are diſtinguiſhed the three Stories: Under the firſt is a large Stand or Foot, which, by means of the Saddles, Faſtenings, and ſloping Supports which keep it up, bears the whole Mill. It turns occaſionally round this Stand to preſent the Vanes or Flights to the Wind, according to the Side it blows. The Handle of the Mill with its Ladder, being puſhed by a Man, or drawn by means of a Windlaſs or Axis *in peritochio*, ſuffices to put the Arbor of the Sweeps in the Direction of the Wind.

In the firſt Story, towards a third of the Timber Work, on the Side of the Sweeps is ſeen the Faſtening or Pin, which bears the whole, protracted to the ſecond Story. Between that Piece of Support, and the fore Part, is ſeen the Trough placed under the Mill Stones to receive the Meal.

In the ſecond is the Drum for the Mill Stones, the Hopper, and the Trundle Head, at the Bottom of the Cog-wheel.

In the third is the Arbor or Axis of the Sweeps, the Cog-wheel, the Ring or Hoop which embraſſes the Cog-wheel, to let it looſe or ſtop it, and an Engine to draw the Corn, which receives its Motion from the Cog-wheel.

The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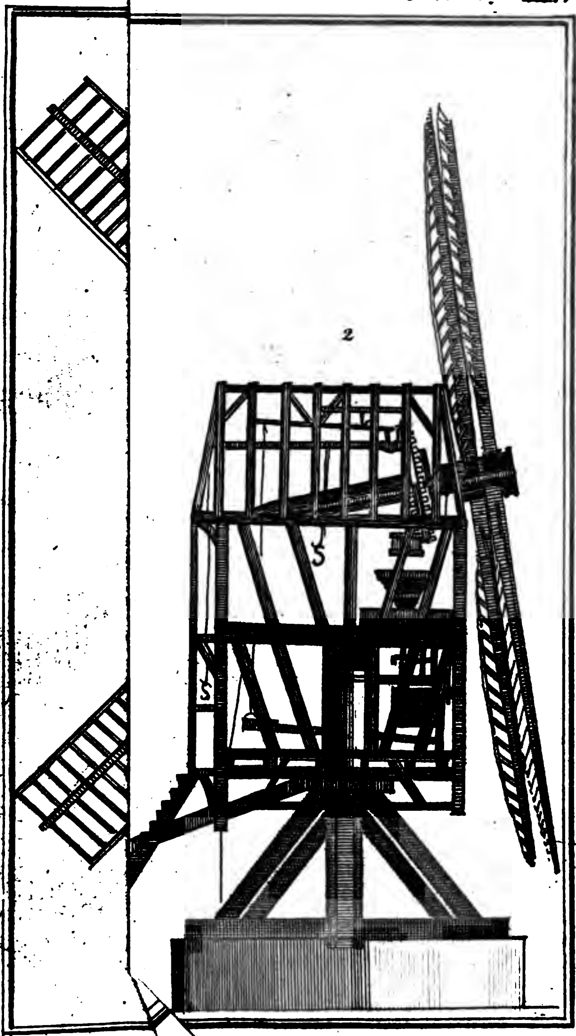


The Beauty of this Machine consists, 1. in the perfect Equilibrium of the Mass of the Mill, which is supported and plays on the Air on a single Pivot. 2. In the Disposition of the Sweeps to receive the Wind. 3. In the Proportion of the moving Force, with the Resistance of the Mill Stones and Frictions.

The Beauty of the Invention,

To make the Timber Work turn round its Pivot in a perfect Equilibrium, the Fastening is not placed in the Middle. The large Lever of the Sweeps, and Weight of the Mill Stones, would bring the whole Machine forwards, but the Pin of Support is much more forwards than backwards, to make the back Part counterpoise the fore Part. The Detail of the Pieces of the Timber Work is very well treated of in the Carpentery of *Jousse*, revised by M. *de la Hire*.

The Equilibrium of the Timber Work.

The Freedom of the Flight of the Sweeps or Vanes, depends on the Inclination of the Axis to the Horizon, and of the Inclination of the Surface of the Vanes to their Axis.

Most Winds, instead of rolling on a Line parallel to the Horizon, make one Angle with the Horizon. When the Wind is a little fresh, if you expose your Hand perpendicularly open to it, the Impression of the Wind is not near so strong as it could be. But if you bend your Hand back, continuing to keep it quite open, you will feel a stronger Impulsion; because, then, the Inside of the Hand is exactly opposite to the Direction of the Wind. Such is the Reason of the Position of the Vanes, *Plate* viii. *Fig.* II. The Axis being inclined on the Floor of the third Story, is found in the Direction of the Wind, and opposite the Surface of the Vanes to that Direction.

The Disposition of the Vanes.

But it does not suffice that the Axis which carries the Vanes be inclined to the Horizon; the Surface of the Vanes, besides, instead of making a right Angle with the Axis, is eighteen Degrees distant from it, on one Part, and forms, on the other, an Angle of 72 Degrees with the Axis. Workmen do not follow any great Uniformity in these Measures: But setting apart the Profits or Advantages

tages more or less, let us search in a few Words the Reason of this Obliquity.

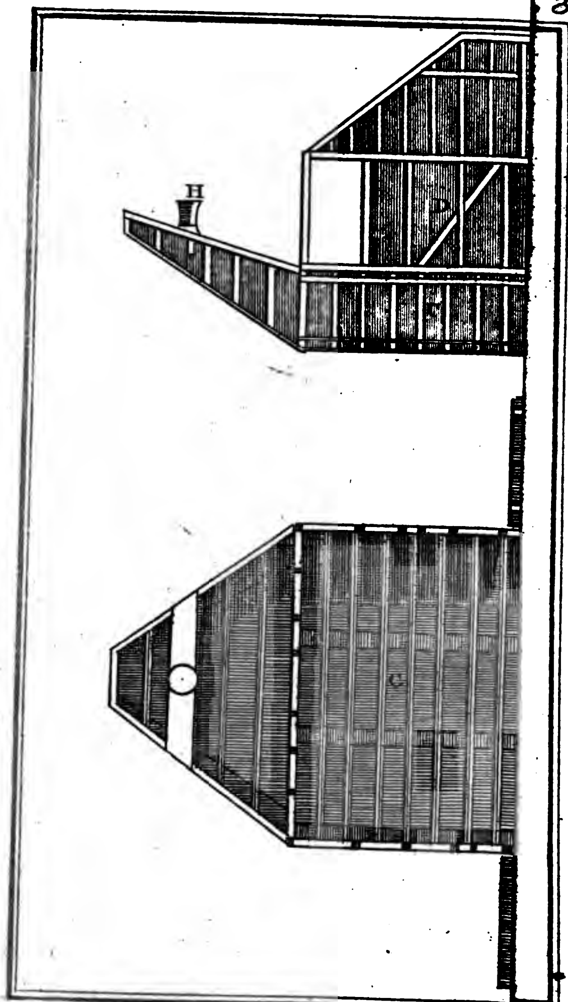
If the Wind should blow directly on Vanes of a flat Surface, and opposite, at right Angles to its Direction, it could by no Means drive the Vanes; because its Action driving one Vane, would be described by a less Action carried on the opposite Vane. There is the same Inconvenience on the Part of the two Portions of the same Vane, which will force the Wind along each Arm. The Wind drives equally to the right and left. What it should gain in making the Vane bend towards the left, it would lose in making it bend as much on the right. What it could obtain in finding an uniform Resistance in the whole Extent of the four Vanes, would be to drive the Mill about.

Let us incline these Vanes of a few Degrees; but let that Inclination, which I suppose on one Vane, of eighteen Degrees one way, and of seventy-two Degrees on the other, with regard to the Axis, be continued the same on the opposite Vane: And on either Side face the Ground. Then the Wind happening to glide on one Vane will drive it, and dispose it to ascend: It does the same on the opposite Vane: Now one of them cannot ascend while the opposite Vane strives to ascend likewise. One Action destroys the other; and nothing moves.

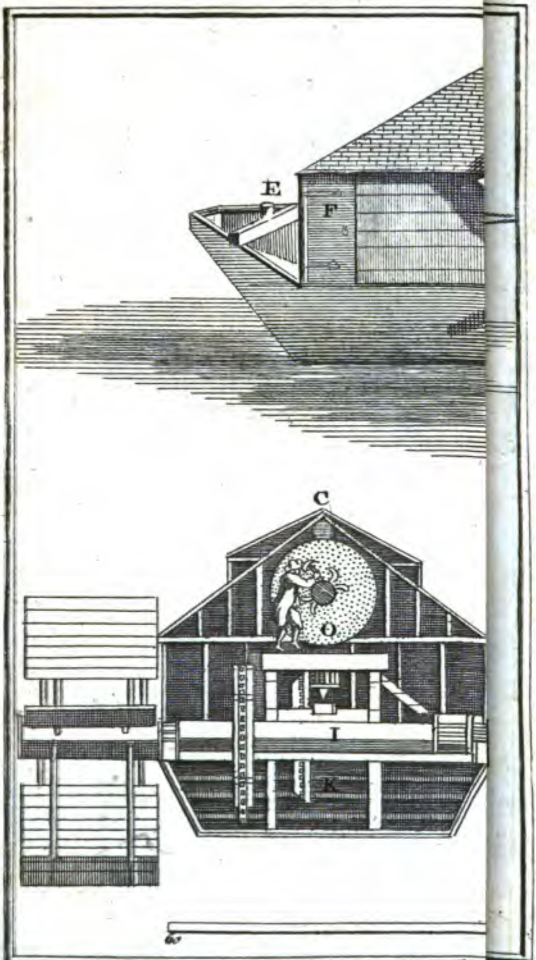
But if the two opposite Vanes are parallel to the Horizon, one averts its Surface of few Degrees from the right Angle, in facing downwards, and the others in facing upwards; the Wind striking against the Surface which inclines downwards, will make it ascend; and gliding, in the same Manner, on the Surface of the opposite Vane, which it finds inclined contrary ways, it will dispose it to descend. One Action helps the other. If two Levers begin to shake the Mill Stones, four disposed with the same Precautions will produce a double Effect.

Such is the simple Artifice of the Motion of the Mill Stones, of the Equilibrium of the Timber Work, and of the Flight of the Vanes. As to the just Quantity of Forces and Resistances, either in Water Mills or Wind Mills, it is a Matter disputed among Engineers; but we have nothing more learned on that Subject, but what hath been written by Mess. *Mariotte* and *Belidor*.

PLATE



A Plan &c.



Elevatio.

PLATE IX. and X.

A Mill on Boats, delineated by M. Leander, *after the Mills of* Paris.

FIG. I. A The Plan of a Water Mill.
C The Bottom of the Boat.
I The Flyers turning.
K The great Arbor, or Axis.
L The Canting-wheel.
M The large Truddle Head, fastened to the small Arbor, as well as the Cog-wheel.
N The Cog-wheel.
O The small Trundle Head which guides the Mill Stone.
FIG. II. B A Section on the Length of a Water Mill.
C The Side of the Bottom of the Boat.
D The watching Place.
E The Roof.
F A Bastard Window.
G The Bit or fastening Piece.
H A Potlock.
N The Cramp-Iron, or a kind of Pivot which supports the Mill Stone.
P The smallest Trundle Head.
O The Cog-wheel, hiding the large Trundle Head.
Q The Mill Hopper.
R The Bell.
FIG. III. A An Elevation of a Mill on Boats.
D The Potlocks.
E The Bit, or fastening Piece.
F The Door.
G The Bridge.
H The Flyers.
FIG. IV. B A Section on the Breadth.
G The Bridge.
I The great Arbor.
K The Canting-wheel.
L The great Trundle Head.

M The

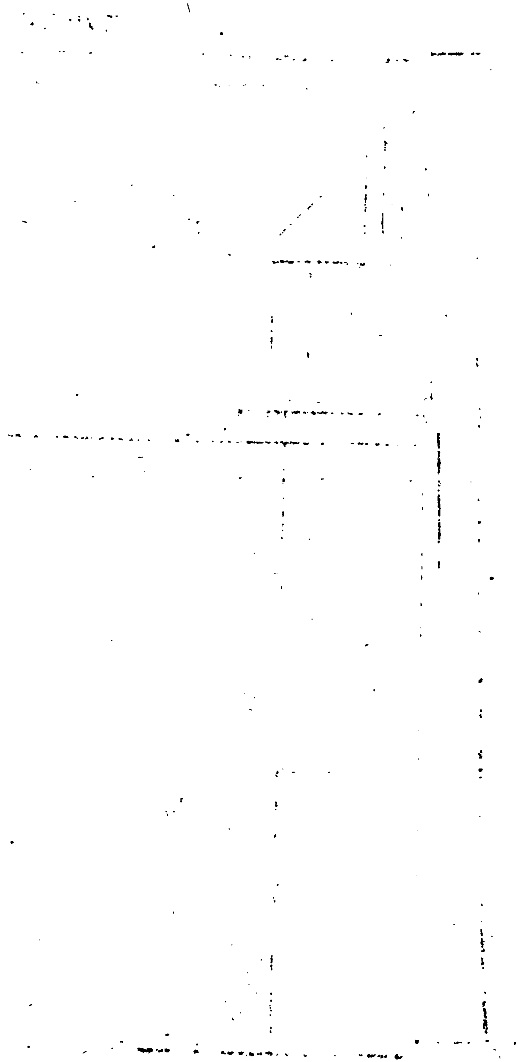
M The Cog-wheel.
N The ſmall Trundle Head.
O The Coffer which contains the Mill Stones.
P The Mill Hopper.
Q The Rope of the Bell.
S A Trough for the Corn.
T The Clapper.
X The Top of the Belfrey.
Y The Bin.
Z A Cable to raiſe the Mill Stone, with its Pulley and Roll.

FIG. V. C Another Section on the Breadth.
I The great Arbor.
K The Cog-wheel.
M The Canting-wheel.
N The ſmall Trundle Head.
O Manner of repairing or beating again the Mill Stone.

All the Pieces which compoſe the Mechaniſm of a Mill are found in the Elevation and Sections of a Mill on Boats ſeen different Ways; which Pieces can be known, at preſent, without being marked; obſerving, only, that there is here a Wheel and a Pinion more than in the other Mills. The Wheel is driven by the Arbor, and the Arbor driven by the Flyers carried off by the Current. This Wheel is implicated into a great Pinion which drives the Cog-wheel on the Trundle Head, deſigned to drive the Mill Stone.

We ſee in the Section which ſhews the hind Part of the Boat, the upper Mill Stone riſen to be muffled. This Work is neceſſary to it, from time to time, to render it a little rough on its whole Surface; it becomes ſmooth in working, and then can only flatten the Corn; whereas acquiring as many Teeth, by being pricked a-new, as it acquires ſmall Points or Inequalities, it becomes as a large File, which cuts and pulverizes all it meets with But as by repairing the Mill Stone, the Thickneſs and Weight thereof is diminiſhed, to reſtore to it the Weight proper to bruiſe, and its juſt Proportion with the moving Power, when it is found too much leſſened, it muſt be charged with a Cake of Plaiſter.

The



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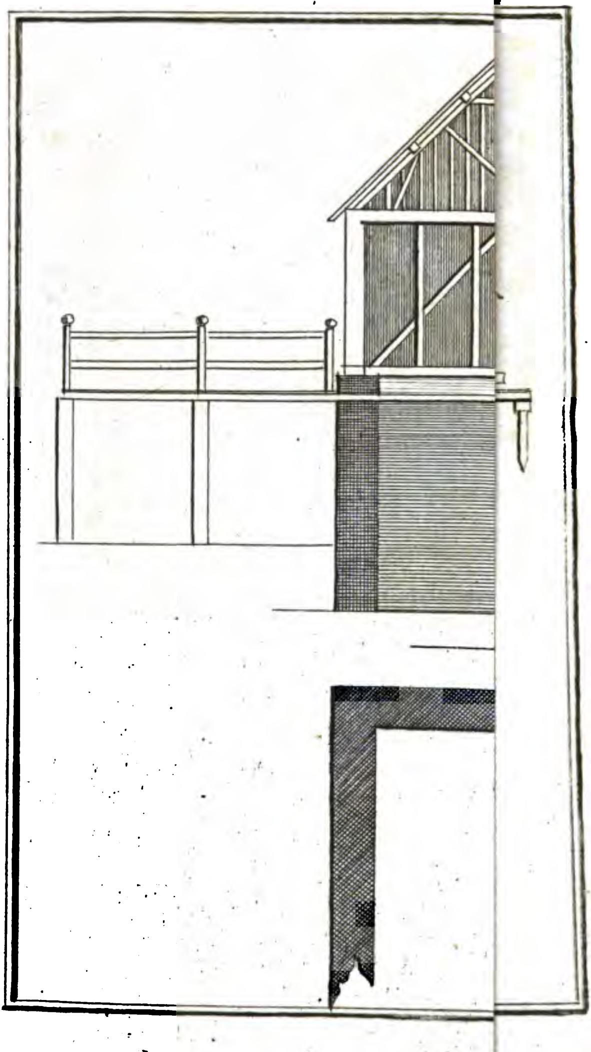
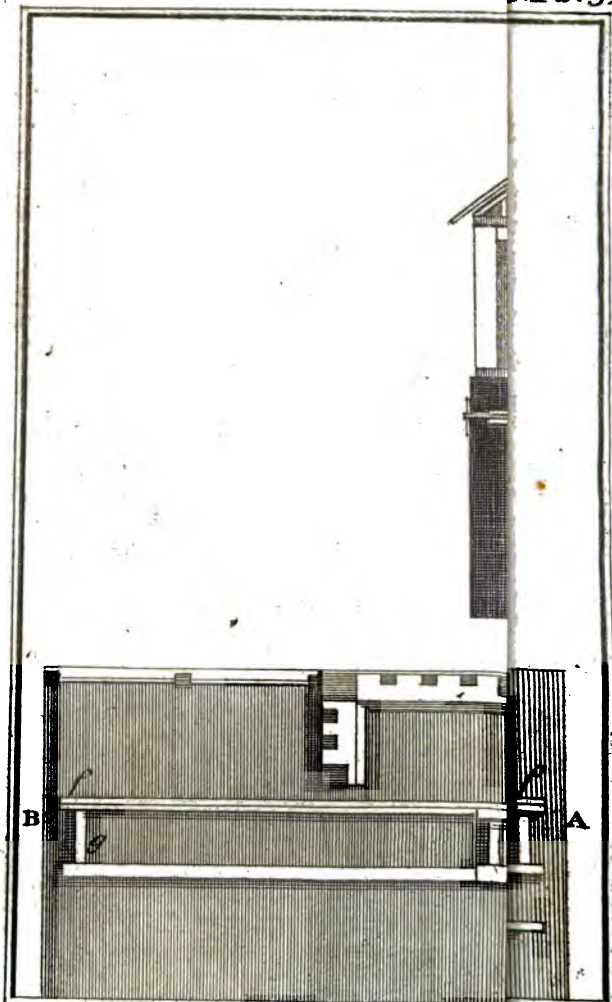




A Plan

The Bell seen on the Side of the Mill Hopper, in the Section of the Length of the Boat, is suspended in the Air, where it is kept fixed, without sounding, by Means of a small Cord, which hangs from the Side of the Mill Hopper, to the Botttom, where it is lowered and kept steady by the Weight of the Corn, while there remains any considerable Quantity of it; but when it is almost all run out, the Cord being no longer stopped gets loose, and restores the Bell to its natural Situation, where it is agitated by the Shakings of the Spout of the Mill Hopper, so as to ring or sound continually, to give the Miller Notice to be ready to fill up the Mill Hopper. If he was not attentive to the Signal, the upper Mill Stone, having no more Corn to work upon, would close with the fixed one, and by rubbing against it, would make Sparkles of Fire fly, which being soon multiplied to a considerable Quantity, would set the Mill and Timber Work on Fire.

PLATE XI, and XII.

A Sawing Mill, delineated by M. Leander *at the* Fere, *and justified on the Figures of M* Belidor.

FIG. I. The Plan of the Cave of the Mill.

M N The Wheel driven by a Fall of Water; it has five Feet and a Quarter of Radius; and its Arbor sixteen Inches.

O The Cog-wheel turning on the same Arbor with the Wheel, and inserting its Teeth on one Part, into the Spindles of the Trundle Head P; and, on the other, into those of the Trundle Head R. The Cog-wheel has two Feet and a half of Radius, and thirty-two Teeth.

P A Trundle Head, which turning makes a broad Handle, fastened to the Iron Blade, go up and down: Which makes also the Saw go up and down.

Q The Handle seen perpendicularly; its Bent is visible in Fig. II.

R Another Trundle Head, which turning with its Axle-tree or Roller S, winds up a Rope, which brings towards

towards the Saw the Chariot on which the Piece of Wood to be ſawed is placed. When the Wood is arrived cloſe to the Saw, the Rope is no longer of Uſe; and there is, then, another Moderator which regulates the Motion of the Piece in Proportion as it is ſawed. The two Trundle Heads have each eight Inches of Radius, and eight Spindles of two Inches nine Lines Diameter.

FIG. II. Profile of the Breadth of the Mill.

M N The Wheel.

O The Cog-wheel.

P The Trundle Head which drives the Saw T.

Q Y The Chaſe, a Blade of Iron faſtened at the Bottom, by means of an Oilet-hole to the Handle, and at the Top in Y, by a Pin to the lower Entertoiſe of the Saw. The Handle, which here is marked Q, is not faſtened to the Arbor, but to the Trundle Head P. The Trundle Head, in going up and down, forces the Handle to make a Semi-turn upwards, and another downwards. This Handle plays in the Oilet-hole of the Iron Blade, and makes it not only go up and down, but alſo backwards and forwards, as it does itſelf.

T The Saw.

X Y The Frame which carries the Saw, and ſlides in going up and down into the Grooves.

Z The Wheel which regulates the Motions of the Chariot; which cannot be underſtood but by the Reſiſtance of the following Figures.

FIG. III. A Plan of the Mill ſeen even with the Ground.

A B The Floor.

f f g g Two Grooves, into which enter the Shafts of the Chariot which carries the Piece to be ſawed, that the Piece ſhould not only advance with the Chariot, but alſo keep ſteady, without reeling, or leaning on the right or left; whence it happens that the Strokes of the Saw work always on the ſame Line.

FIG. IV. O The Cog-wheel.

R The Trundle Head, which makes the Rope, faſtened to the Chariot, ſpin on its Roller.

r r The Chariot carrying the Piece of Wood to be ſawed.

P The

P The Trundle Head which drives the Handle, and the Blade faſtened to the Saw.

X Y The Iron Blade eight Feet long, called the Chaſe.

T The Saw larger at Top than at Bottom.

c b An Iron Rod of twenty two Inches, faſtened on one Side with a large Pin to the upper Entertoiſe of the Saw, and on the other to a moving Lever, which goes up and down along with it.

a c The moving Lever joined ſquare-wiſe with the Arm *g*.

g The Arm or Piece of Wood moving on an Iron Pin ſix Inches above its Union with the Lever *a c*.

d e A Shaft or wooden Handle of eleven Feet ſix Inches, which carries at its Extremity *a*, an Iron in the Form of the Foot of a Hind to enter the Teeth.

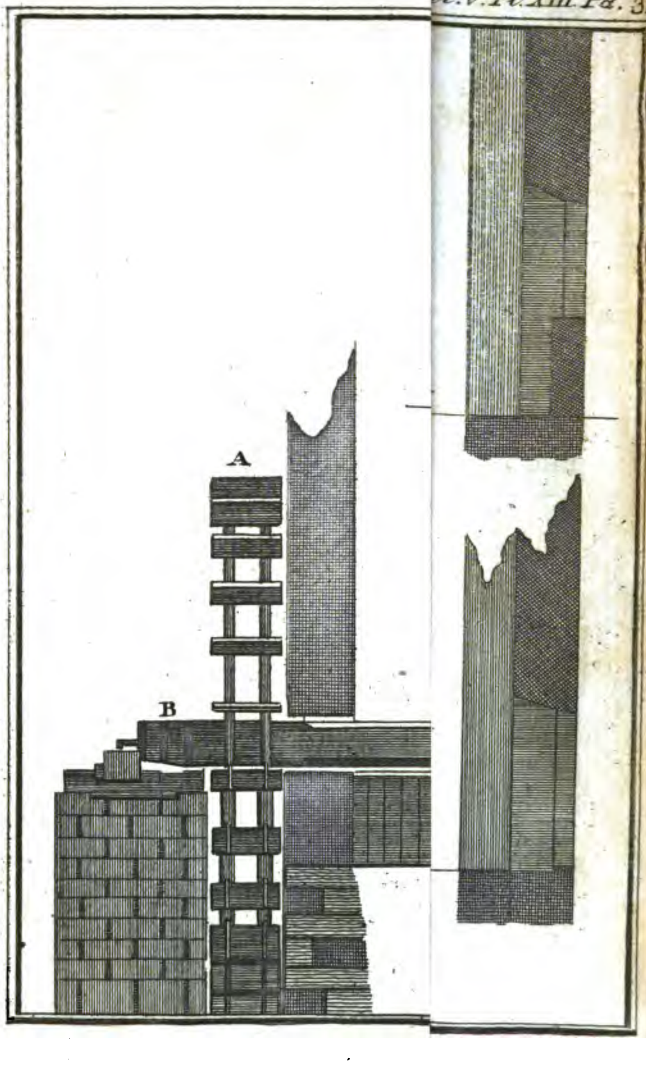
Z The Cramp-wheel, of three Feet four Inches diameter, the dented Circle included, and carrying 384 Notches, or hooked Teeth, like thoſe of a Pot-hanger, each four Lines broad, and two Lines and a half long.

The Axis of this Wheel drives two ſmall Trundle Heads of ten Inches diameter, and the Spindle thereof, eight in Number, each of ſixteen Lines diameter, are inſerted into the Teeth, which line the undermoſt Part of the Shafts of the Chariot. If the Cramp-wheel advances, the Chariot muſt advance, and the Piece of Wood likewiſe. If the Wheel Z ſtops, the Piece of Wood ſtops alſo.

Before we explain the Motion of all theſe Pieces, we muſt obſerve that, at preſent, inſtead of the moving Arm *g*, they employ an Axle-tree of ſix Inches Radius, turning on two Trunnions. To that Axle-tree is faſtened the Lever *a c*; ſo that if the Lever goes up or down, the Axle-tree rolls likewiſe. The Handle *e d* is faſtened at the Bottom of this Axle-tree with a Hinge: If therefore the Axle-tree turns in aſcending with its Lever, it brings the Hinge *d* towards *e*: The Handle muſt protract itſelf at that Inſtant, and drive a Tooth of the Cramp-wheel Z. If the Arm or Axle-tree, driven back by the Fall of the Lever *c*, brings down the Hinge, the Handle *d e* makes

makes an Elbow with that Hinge, and grows ſhorter. The hind Foot *e* therefore muſt fall back beyond another Tooth of the Cramp wheel. A Clapper ſuffers the Wheel Z to turn one way, but catches or ſeizes the Notches thereof in ſuch a manner as to hinder it from turning another way. We may eaſily underſtand the Communication of the Motion and its Effect.

After the Rope, by ſpinning on the Axis of the Trundle Head R, has brought the Chariot and piece of Wood as far as near the Saw, the Trundle Head P is let looſe to the Cog wheel, which makes the Handle and the Chaſe QY go up and down. That Blade cannot go up without making the Saw go up. The Saw, in aſcending, with the other Blade *b*, lifts up the Lever *a e*, which conſequently draws the Hinge *d* on the ſame Side. Therefore the Handle muſt protract itſelf towards *e*, and drive farther a Notch of the Cramp-wheel Z. This Cramp-wheel in turning with its Axis drives the Trundle Heads, which inſerting their Spindles into the Teeth of the Shafts of the Chariot carry off ſome of them, and make the Piece of Wood to come a little forwards. The Motion we ſpeak of is that whereby the Saw aſcends: and as it is larger at the Top than at the Bottom, it leaves, at that Inſtant, an empty Space between itſelf, and the Piece of Wood it has bit. The Wood advances without any Obſtacles, and receives a new Stroke in the Fall of the Saw, which here, works only in going down, as in the Hands of Sawyers in length. The Saw muſt go down, becauſe the Handle which has raiſed it falls at that Inſtant, and brings back the Chaſe, Saw, the Iron Rod *b*, and the Lever *a c*. The Wheel Z is at that Time without Motion, and communicates none to the Chariot. It is during that Reſt of the Piece of Wood, that the Stroke of the Saw is given, and as the Saw is larger at the Top than at the Bottom, it leans on the Length of the Wood, which is alſo an ingenious Imitation of the Sawyers of Planks, who bring back the Saw, not to the perpendicular, but obliquely or ſloping, becauſe the Fibres of the Wood are not eaſily cut, when the Cut is tranſverſal, whereas they obey when it is oblique; and as the Arms of the Sawyers move backwards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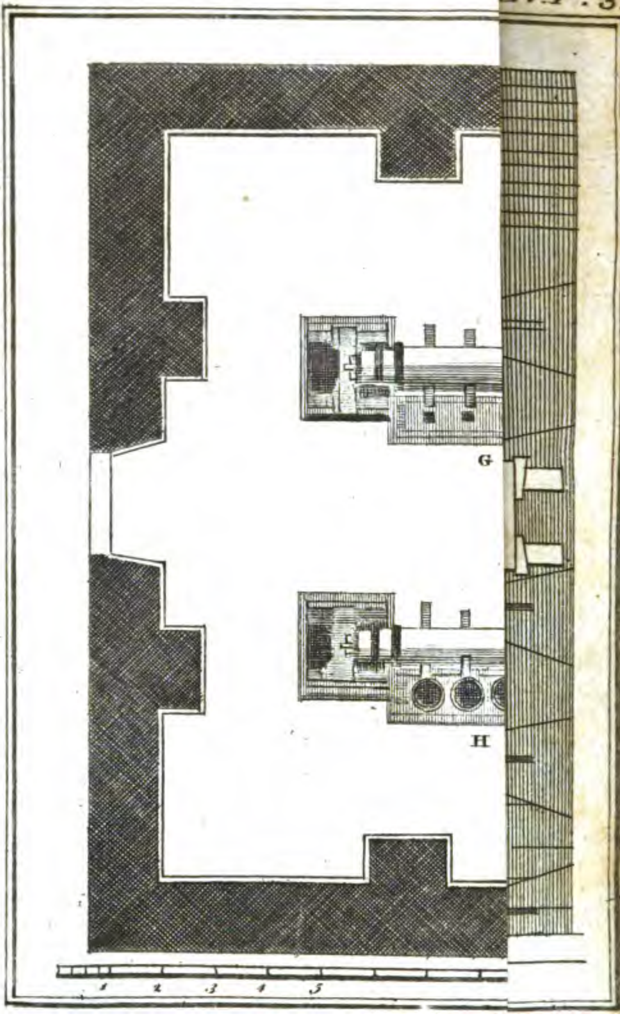
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wards and forwards occasionally, to give the Saw a proper Inclination on the Fibres of the Wood, thus the upper Iron Rod and the Chaſe obey the Motion of the Lever and Handle, ſo as to form with the Saw the Angles and Inflexions neceſſary to make the Grooves move backwards and forwards. The ſame Play begins again. The Shafts always drawn along in their Grooves *f f g g*, by the Trundle Heads of the Wheel Z continue to bring the Piece of Wood under the Saw, till a Band of Iron faſtened to the Extremity of the Piece of Wood, meets with a Trigger which draws out the Pin which had been applied to the Flood Gate to keep it up, and let the Water run. The Flood Gate falls, the Water ſtops, and all the Machine is without Motion.

A Saw Mill will cleave in two a Joiſt of a moderate Thickneſs, in one Hour's Time, which two ſtrong Sawyers would ſcarce be able to do in four or five.

PLATES XIII, and XIV.

A Powder-Mill delineated by M. Leander,

Gunpowder is compoſed of Salt-Petre, Sulphur, and Charcoal. The Sulphur muſt be well purified. Salt-Petre is a Salt extracted by different Liminations from ſeveral Sorts of broken Stones, Pieces of old and dry Plaiſter, or Rubbiſh of old Buildings, eſpecially Cellars, and generally all Earths which have been long in Sheep Folds, Stables, Pigeon Houſes, and other Places where are gathered, either by a regular Courſe or Tranſpiration, the Drainings of Dunghills, Manufactures, Urines, and all Salts proceeding from Animals. Theſe three Matters pulverized ſeparately are incorporated afterwards into one Maſs of a fixed Weight, whereof the Salt-Petre makes three Quarters, the Sulphur half a Quarter, and the Charcoal the other half Quarter. The Sulphur ſerves to inflame the Whole. The Charcoal hinders its too ſudden Extinction. The Salt-Petre makes its Strength, by the great Dilation it receives from the Fire, and Hardneſs of the Parts it ſhoots. What we can diſcover

in

in the terrible Action of Gun-powder is extremely confined, tho' we have learned by several Experiments to make it and manage it. The Ingredients, which enter its Composition, are harmless, while they remain separate; and it could be wished, for the Repose of Sailors, and those who have Gun-powder in their Neighbourhood, that all those Matters could be exported, or kept separate, till a present Occasion should require to join them together. This would be an important Service to Society: I ask it of them who want nothing else for the Formation of the World but Matter and Motion. But till they be pleased to favour us with it, we will continue to make the Incorporation of the three Matters Gun-powder is composed of, in the Mortars of the Mill with the Assistance of the Pestles and Sprinkling. The Mortar is a Piece of Wood made to receive twenty Pounds of Paste of the Composition abovementioned. There are twenty four Mortars in each Mill; where are made, at once, and in one Day, four hundred and eighty Pounds of Gun-powder, by sprinkling each Mortar with two Pounds of Water, taking care to repeat the Sprinkling, from time to time, lest the Matter should take Fire. The Paste having been pounded during three Hours successively, it passes from one Mortar into another. The Mortar is pierced at Bottom, and stopped with a Cork or Piece of Wood in the Form of a Cone, to receive the Strokes of the Pestles, and reserve the Mortar. The Pestle is a Piece of Wood ten Feet high, and four Inches and a half broad, armed at Bottom with a round Piece of Metal. The Pestle weighs sixty five Pounds. The Inspection of the Pieces will make us conceive the Effect thereof,

FIG. I. The Plan of the Wheel and Trundle Heads.

A The Wheel driven by a Fall of Water.

B The Arbor of the Wheel.

C D Two Trundle Heads, each turning with their proper Arbor.

E The Cog-wheel, driven by the Arbor of the great Wheel, and inserting its Teeth between the Spindles of the Trundle Heads, which makes one of them turn one way, and the other another Way.

FIG.

FIG. II. The Profile of the Wheel and Cog-wheel.

A The Wheel.

B b The Arbor of the great Wheel. It places one Trunnion in *b*, and the other in B.

C The Aıbor of the Trundle Head C ſeen beyond the Cog-wheel.

E The Cog-wheel, from before which the Trundle Head D has been taken off here.

F The Peſtles.

G The Tails of the Peſtles; which are two Pieces of Wood, pierced with as many Holes as there are Peſtles, to keep them even in the ſame Row, while they go up and down.

H The Outſide of the Mortars.

FIG. III. The Plan of the whole Machine.

A The Wheel.

B The Arbor.

C D The Two Trundle Heads, each with its proper Arbor, called here Canting-wheel. The Axis which makes the Trundle Head turn is called Canting-wheel, being environed with twelve ſmall Pieces of Wood jutting out; theſe Pieces are called Lifts, becauſe they are deſigned to raiſe the Peſtles, they catch them by the meeting of another Piece of Wood faſtened laterally to each Peſtle. Theſe Faſtenings are called Stays.

E The Cog-wheel.

G The Tails of the Peſtles.

H The Bottom of the Mortars.

If Water be given to the Wheel, the Cog-wheel muſt march and drive contrary Ways the two Trundle Heads and their Canting-wheels. Each Lift turning with the Canting-wheel, meets at its Return with the Stay of a Peſtle, and lets it fall into its Mortar. Theſe twelve Lifts are diſpoſed in ſuch a Manner that there is always four of them up, and four Peſtles unequally ready to fall. There is but one of them that falls at a time. From that Diſpoſition of the Peſtles depends the Equality of the Trituration of the Peſtle. Which ſucceeds ſtill better, by making it paſs through the twenty four Mortars at regular Times.